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CODE CUGEL

A CODE TO UNFOLD Ge(Li)  
SPECTROMETER POLYENERGETIC  
GAMMA PHOTON  
EXPERIMENTAL DISTRIBUTIONS

July 1970

Prepared by

J. J. Steyn  
and  
U. Born

For

JET PROPULSION LABORATORY  
California Institute of Technology  
Pasadena, California

NUS CORPORATION  
4 Research Place  
Rockville, Maryland 20850

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JET PROPULSION LABORATORY  
CALIFORNIA INSTITUTE OF TECHNOLOGY  
PASADENA, CALIFORNIA

NUS CORPORATION  
4 Research Place  
Rockville, Maryland 20850

Approved: 

E. A. Saltarelli  
Vice President and Technical Director

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## SUMMARY

A FORTRAN code has been developed for the UNIVAC-1108 digital computer to unfold lithium-drifted germanium semiconductor spectrometer polyenergetic gamma photon experimental distributions. It was specifically designed to analyze the combination continuous and monoenergetic gamma radiation field of radioisotope volumetric sources. The code generates the detector system response matrix function and applies it to the monoenergetic spectral components discretely and to the continuum iteratively. It corrects for system drift, source decay, background, and detection efficiency. Results are presented in digital form for differential and integrated photon number and energy distributions, and exposure dose.

## 1. INTRODUCTION

This report presents a description of and the user requirements for, code CUGEL - - - a digital computer code to unfold semiconductor spectrometer polyenergetic gamma photon experimental distributions developed for the JET PROPULSION LABORATORY under Contract No. 952706. Code CUGEL, written in the FORTRAN V language for the JPL UNIVAC-1108 digital computer, is a very much modified and redesigned version of code CUPED which was developed under contracts NAS5-10133 and NAS5-10337 for NASA- Goddard Space Flight Center<sup>(1-4)</sup>. The experimental distributions which the code has been specifically developed to analyze, are those recorded by the germanium (lithium-drifted) - - - Ge(Li) - - - semiconductor detector coupled to a multichannel pulse-height analyzer and exposed to the continuous and line energy photons emitted by radioisotope volumetric sources.

The code can either read or generate the detector system response function matrix and apply it to unfold the pulse-height analyzer distributions to determine differential and integrated photon number and energy distributions, and exposure dose. The response matrix generation procedure relies on the spectra of standard radioisotopes such as Cd<sup>109</sup>, Ce<sup>139</sup>, Hg<sup>203</sup>, Sr<sup>85</sup>, Cs<sup>137</sup>, Nb<sup>95</sup>, Mn<sup>54</sup>, Zn<sup>65</sup> and Co<sup>60</sup>. The standard spectra are normalized with respect to photopeak pulse-height and area, and their photopeaks subtracted to obtain normalized Compton continua. The response matrix vectors are determined at each energy by interpolating the normalized continua and computing the associated Gaussian photopeaks. The thus interpolated vectors are redistributed in pulse-height to correspond to the detector system energy response and to satisfy the requirements of the spectra to be unfolded. Quadratic interpolation of the normalized continua is carried out by a specifically developed 'Method of Parts', described in this report.

Code CUGEL applies the response function either iteratively or discretely depending on whether the unknown is either a continuous spectrum, a complex spectrum consisting of a limited number of photopeaks or a spectrum consisting of a continuum-plus-photopeaks. The code determines the detector incident photon lines in the unknown spectra by photopeak analysis. The corresponding photopeak associated Compton continua are determined by an interpolation of the standard Compton continua. The thus determined photopeak-plus-continuum spectra are then subtracted to leave, ideally, either a continuous or zero residual spectrum. Continuous and residual spectra are iteratively unfolded according to the matrix inversion technique of Scofield<sup>(5-8)</sup>, to determine detector-incident continuous photon spectra. The total incident gamma photon spectrum is determined as the sum of the line and continuous components.

The code corrects for partial photon energy deposition in the Ge(Li) detector through the application of the response function matrix. It corrects for the number of photon interactions in the detector crystal and for absorptions by the crystal cladding materials, interposed absorbers such as aluminum and the air medium between the source and the detector active region. In addition, it corrects for primary source decay, pulse-height drift and natural background.



## 2. CODE DESCRIPTION

### 2.1 INTRODUCTION

Code CUGEL is written in the FORTRAN V compiler language for the JPL UNIVAC-1108 digital computer. It was designed to run under the Executive 8 monitor system at the Jet Propulsion Laboratory. Input data are read from card-to-tape - - - TAPE 5, digital output is written on tape for print out - - - TAPE 6. The code calls only standard library subroutines, such as transcendental functions. Although CUGEL is designed for the UNIVAC-1108 it may be readily adapted to CDC and IBM machines. It has a total word size requirement of less ~ than 65000.

The code consists of a main control program and thirty subprograms. A subprogram glossary is given in Appendix I, in alphabetic name order, and a code FORTRAN punch card deck listing in Appendix II. Appendix III consists of a sample input card deck listing and Appendix IV of a program output listing corresponding to the input given in Appendix III: the execution time for the sample data was approximately 70 seconds with compile and loading time being approximately 45 seconds.

The logic and function of the main program, referred to as MAIN, and its subprograms are discussed in Section 2.2, in some detail. Those subprograms not discussed are considered as being adequately described in either Appendix I or references (1) through (4). The user is also referred to these same references for the theoretical bases of the precursor code, CUPED. The constants required by the code are explained in Section 2.3. Reference to this Section will allow the user to make changes as necessary, in for example, the relationship of such as the detector system photopeak resolution function. The general logic of code CUGEL is discussed

in Section 3.1. The code input is detailed in Section 3.2, and the output is defined in Section 3.3. FORTRAN names and variables are shown capitalized in what follows, with 'zero' and 'oh' thus: 0, Ø.

## 2.2 CODE LOGIC

### 2.2.1 MAIN PROGRAM

The main program was designed to execute data input and output operations, many of them under initially input option signals, and provide the control connectivity for the hierarchy of thirty subprograms presented in Figure 1. Figure 2 shows a simplified flow diagram of the main program; the called subprograms are:

RESFUN	GANF	DEC	DISCRT
SØLN	DECAY	GEØMTR	DETECT

Subprogram RESFUN is called by MAIN to generate and return the detector system response matrix and the associated vectors relating pulse-height to photon energy; photopeak-area-to-total-spectrum-area ratios (experimental photofractions, for code check purposes); and standard spectra photopeak mean pulse-height and resolution. Under control of an input option signal, the response matrix and its associated vectors may be read as a card deck, instead of generated. For the analysis of many sets of unknown spectra one response matrix may be applicable, and thus the main program includes an option to bypass either the calling of RESFUN or the input of a matrix card deck. For similar reasons an option is provided to call RESFUN to generate a response matrix based on previously input standard spectra.

Input options allow either the execution of MAIN to continue, return to start or call EXIT, after the calling of RESFUN. Thus, for example, the code may be run only for the purpose of generating a response matrix.

Unknown spectra may be input to the code in uninterrupted blocks of up to 20 spectra through the calling of subprogram DEC by MAIN. If pulse-height analyzer background subtracted counts are recorded in a complement mode, i.e. as positive numbers, the code converts them to true negative numbers in subprogram DEC. A count greater than  $9 \times 10^5$  is assumed to be in the complement mode.

MAIN is coded to subtract background spectra from source-plus-background spectra under an input option control signal. This allows the subtraction or addition, of a fraction or multiple of a background spectrum. It further allows the continued reuse, as desired, of a previously stored background spectrum, and of course the addition of similar spectra if this is the requirement of the user.

The energy correspondence of an unknown spectrum to the response function matrix is matched through MAIN calling subprogram GANE<sup>(1,2,9,10)</sup>.

Subprogram GANE returns the unknown spectrum to the main program after normalization to pulse-height analyzer true zero pulse-height and gain changing such that channel width corresponds to that of the response matrix.

Additional automated modification of an unknown spectrum may be optionally carried out by the code, namely:

- (a) the counts in the first n 'dead' channels of the spectrum may be replaced with either the count stored in channel  $n + 1$  or determined by a straight line function of specified slope; and/or

- (b) the counts between specified limiting channels may be replaced by counts determined by a straight line function of specified slope.

Item (a) allows the user to make judgments with respect to the first few percent of the spectrum which is often either suspect or electronically distorted. Item (b) allows the removal of a known spurious peak, etc. in order to allow more meaningful subsequent analysis to be carried out.

At this point in the main program on both the first and subsequent loops, the response matrix is stored, and an unknown pulse-height analyzer spectrum is ready for analysis and conversion to a photon number spectrum. According to an input option signal the code is instructed that the unknown spectrum is either a pure continuum or a specified number of monoenergetic spectra "super-imposed" on a continuous spectrum. If the input option indicates the presence of superimposed monoenergetic spectra and if either their line energies and/or photopeak tail channel limits are input, MAIN calls subprogram DISCRT prior to calling subprogram SOLN to carry out iterative unfolding of the continuum. In the event that neither the energies or channel limits of the unknown spectrum peaks are input they may optionally be 'searched-for' from channel MS to MX in subprogram FIND, which is called by DISCRT.

Subprogram DISCRT is called by MAIN to analyze the photopeaks indicated by the input options for the monoenergetic components of the unknown spectrum. Gaussian distributions may be fitted to each photopeak and the associated Compton continua determined by DISCRT calling subprogram RESFUN and the corresponding line photon numbers calculated. In this manner the monoenergetic spectral components may be calculated in turn and subtracted, i.e. stripped, from the unknown spectrum to leave a residual continuum spectrum. The residual spectrum is returned to MAIN

for subsequent analysis and unfolding. The monoenergetic photon numbers thus obtained are added to the residual photon number spectrum determined later by unfolding, to give the total photon number corresponding to the input pulse-height analyzer spectrum. If the photopeak is distributed over less than 6 channels a Gaussian function will not be fitted. In this last event the peak pulse-height and area will be obtained by moments and channel summation analysis, respectively.

Before calling subprogram SØLN the code tests certain input options, M(I), to determine specific requirements, e.g.

(a) is unknown spectrum to be corrected for detection efficiency by calling subprogram DETECT prior to gain changing, (eg. from 200 to 30 channels) and before unfolding or after?; or

(b) is unknown spectrum to be actually unfolded?

Item (a) allows the user to make decisions with respect to efficiency correction effects and accuracies. Item (b) allows the user to make decisions with respect to such as the significance of actually carrying out the unfolding procedure on a low energy spectrum such as that of  $\text{Pm}^{147}$ . The above options and all others, are defined in more detail in Section 3.2. The called subprograms RESFUN, DISCRT, DETECT, SØLN and GEØMTR are discussed further in Subsections 2.2.2 through 2.2.7.

At this point in the main program on both the first and subsequent loops, unknown spectra are considered as prepared for unfolding, and thus, they and the response matrix are communicated to subprogram SØLN. This subprogram is called by MAIN to control the iterative unfolding process according to the Scofield method<sup>(2,5,6)</sup> and to apply efficiency corrections. It returns the corrected photon number spectrum to the main program.

The main program calls subprogram DECAY to determine the primary source decay factor. Subprogram DECAY returns a correction factor by which the number spectrum is later multiplied. The calling of subprogram DECAY may be optionally bypassed, in which case a multiplying factor of unity is assumed.

Subprogram GEOMTR is called by the main program to apply the decay correction factor, carry out geometrical corrections, compute differential and integral photon number and energy distributions, and exposure dose.

Subprogram GEOMTR returns the final results to the main program for output, after which the code loops back along either paths 1, 2, or 3, as shown in Figure 2. The code loops back along path 1 primarily to read new data pertaining either to the response matrix or to the control options or both. The code loops back along path 2 to read new data pertaining either to the unknown source or if the maximum number (20) of allowable passes along path 3 have been equaled; the second reason is dictated by either code DIMENSION or computer finite capacity. The code loops back along path 3 to read a new unknown spectrum

## 2.2.2 RESPONSE FUNCTION MATRIX

### 2.2.2.1 Response Matrix Generation

The detector system response function matrix is generated under the control of subprogram RESFUN. The subprograms called by RESFUN are namely:

SPNØRM	POGELI	BS	XPLØT	
ADPEAK	GANE	TE	TA	VECTMX

The main program supplies RESFUN with control parameters, and variables. RESFUN begins execution by input of a card deck of spectra of standard radioisotopes. The number of such spectra is equal to NSTAND, where  $NSTAND \leq 9$ . This card deck is preceded by one parameter card containing information regarding the number of spectra in the deck (NSTAND) and the number of channels in the input standards (NXLIM). The single parameter card is followed by a card set of NSTAND spectra. Each spectrum is preceded by one parameter card and is input in order of energy ascendance. The parameter card for each spectrum contains the source identity, data regarding peak approximate locations and the deviation of the spectrum from true zero pulse-height, i.e. the  $\pm$  normalizing spectrum shift required; further details are referred to Section 3.

The standard source spectra allowed by the code must be monoenergetic e.g.

Cd <sup>109</sup>	Ce <sup>139</sup>	Hg <sup>203</sup>	Cr <sup>51</sup>
Mn <sup>54</sup>	Nb <sup>95</sup>	Sr <sup>85</sup>	Cs <sup>137</sup>

Zn<sup>65</sup> and Na<sup>22</sup> are allowed if Sr<sup>85</sup> has been input; Zn<sup>65</sup> is preferred to Na<sup>22</sup> because of the 0.51 MeV photopeak intensity relative to the high energy photopeak.

The code as presently designed also allows the inclusion of  $\text{Co}^{60}$  and 'hand' prepared monoenergetic spectra of higher energies, e.g. the sample data in this report includes a hand modified spectrum of  $\text{Th}^{228}$ .

According to an input option and after the first call, calling of RESFUN by MAIN allows the by-passing of input of standard spectra. This allows the code to generate a response matrix based on already stored and normalized standard spectra. Similarly subprogram DISCRT calls RESFUN to determine Compton continua based on already stored current standard spectra.

After spectral data is input to RESFUN, counts in the complement mode are converted to their true negative value. The spectra are shifted to true-zero pulse-height by the calling of subprogram GANE. Their order of input is established prior to the calling of subprogram SPNØRM for spectral normalization.

Subprogram SPNØRM is called by subprogram RESFUN to normalize the single-photopeak and  $\text{Zn}^{65}$  standard spectra with respect to photopeak area and pulse-height; photopeaks and source-characteristic X-ray peaks are subtracted. The multipeak spectrum of  $\text{Co}^{60}$  is normalized in RESFUN after the return from SPNØRM. The residual spectra determined by SPNØRM (and RESFUN in the case of  $\text{Co}^{60}$ ) consist of Compton continua characteristic of the primary photon energy. X-ray peaks are optionally subtracted where they are not representative of the primary photon energy but rather of the radioisotope source. The 0.51 MeV component photopeaks and their Compton continua are subtracted for the same reason. Figure 3 shows a typical set of spectral continua in the energy domain 0.166 MeV to 2.615 MeV, normalized by subprogram SPNØRM as described in Section 2.2.2.2.



Subprogram SPNORM returns the normalized differential standard Compton distributions to subprogram RESFUN. The energy ordered normalized continua are interpolated quadratically with respect to the energy axis of the desired response function matrix through subprogram RESFUN calling subprogram POGELI. The result of this interpolation consists of N (corresponding to the required matrix size) Compton continuum vectors normalized to unit photopeak area and pulse-height. Subprogram DISCRT similarly calls RESFUN to obtain interpolated normalized Compton continua over a required number of channels and at the specific energies corresponding to photopeak analysis.

Unit area and mean pulse-height Gaussian photopeaks are added to the interpolated differential Compton continua to give N (matrix size) complete spectra (matrix vectors). The peaks are computed through RESFUN calling subprogram ADPEAK. The Gaussian photon energy dependent standard deviation  $\sigma(E)$ , is determined by interpolation of those values obtained by the earlier photopeak fitting. Subprogram ADPEAK computes a Gaussian photopeak histogram in accord with the methods described for Equation (4) in Section 2.2.2.3 of this report. The N determined unit size differential spectra are redistributed linearly in pulse-height as a function of photon energy. The redistribution is obtained through RESFUN calling subprogram GANE.

At this point in the subprogram RESFUN execution, a response function matrix has been determined. This matrix and its corresponding vectors for pulse-height photon energy and photofraction are returned to the main program. Figure 4 compares the photofractions of the response matrix vectors as determined by RESFUN with actual values separately determined for the standard source experimental spectra.

#### 2.2.2.2 Spectrum Normalization

Subprogram SPNØRM normalizes the standard spectra input to RESFUN. It begins execution by carrying out necessary initializations. SPNØRM calls subprogram PKFUN to carry out a Gaussian fit to the spectral photopeaks. Subprogram PKFUN estimates the necessary initial values of the peak function parameters: straight-line-base slope and intercept, Gaussian photopeak standard deviation, area and mean pulse-height. Subprogram PKFUN returns the parameters of the fitted and subtracted photopeaks and the residual spectra to subprogram SPNØRM. Subprogram PKFUN calls subprogram STDFT3 to carry out the non-linear regression of the peak function. The peak function is obtained by STDFT3 calling subprogram FUNZ.

Subprogram SPNØRM uses the determined photopeak pulse-height and area parameters to normalize the continua of the standard spectra. A subtraction of the characteristic X-ray peaks is carried out in the case of those spectra where they occur. The 0.51 MeV photopeak and continuum of  $\text{Sr}^{85}$ , if it has been input, is employed to subtract the 0.51 MeV spectrum contribution of  $\text{Zn}^{65}$ . This operation requires both count and pulse-height gain normalization, the gain normalization being carried out through the calling of subprogram GANE.

The residual Compton continua are gain normalized to a photopeak pulse-height of NØRM (e.g. = 200) channels by the calling of subprogram GANE and count normalized to unit photopeak area by a division operation.

The resulting residual normalized continua are checked for negative count values, which are replaced by zero, and returned to the calling subprogram RESFUN. The fitted photopeak parameters are also returned to subprogram RESFUN.

The two-component spectrum of  $\text{Co}^{60}$  is normalized in RESFUN, although the photopeaks are subtracted under the control of SPNØRM. The normalization is actually carried out on the 1.33 MeV contribution only, the 1.17 MeV contribution being discarded. The 1.33 MeV continuum is obtained as the residual remaining in the input  $\text{Co}^{60}$  continuum after subtraction of the 1.17 MeV continuum. The 1.17 MeV continuum is obtained by an extrapolation in subprogram POGELI based on the three highest energy standard normalized continua (e.g.  $\text{Cs}^{137}$ ,  $\text{Mn}^{54}$  and  $\text{Zn}^{65}$ ). The 1.33 MeV residual continua so found is then normalized and included as a member of the previously determined set of standards. Figure 3 shows an example 1.33 MeV continuum and Figure 4 the photofraction determined by the code.

#### 2.2.2.3 Photopeak Fitting

Subprogram SPNØRM calls PKFUN, which in turn calls STDFT3, to fit the photopeaks of the standard source spectra with a 'Gaussian-plus-straight-line-base' function. Under options discussed in Section 2.2.4., subprogram DISCRT calls STDFT3 to fit the photopeaks in the unknown spectrum with the same function. As presently coded PKFUN requires that only the standard source energy and the approximate peak location be specified by SPNØRM.

Initial estimates of the photopeak function parameters, which are regression fitted in STDFT3, are determined in PKFUN. The mean pulse-height parameter B (1) is estimated from the channel of maximum count in the vicinity

of the specified approximate channel location of the peak. The standard deviation parameter  $B(2)$ , of the Gaussian, is obtained from the expression

$$B(2) = \sigma(B(1)/E), \text{ channels}, \quad (1)$$

where

$$\sigma = 0.001536 \exp(0.395 * E), \text{ MeV}, \quad (2)$$

and

$$E = \text{photon energy corresponding to specific photopeak, MeV.}$$

Figure 5 compares the above expression for  $\sigma$  with the regression fitted values obtained for the JPL standard spectra. The area parameter of the Gaussian  $B(3)$ , is initially estimated from the expression

$$B(3) = H * B(2) * 2.35, \text{ counts}, \quad (3)$$

where

$$H = \text{count above straight-line-base in channel of maximum count i.e. in channel } B(1),$$

$$2.35 = \text{a Gaussian constant relating standard deviation to width at half of maximum peak height.}$$

The photopeak base is taken as the straight line between the counts in the channels defined by  $[B(1) \pm 6.0 * B(2), \text{ rounded up or down to integer}]$ .

Subprogram STDFT3 is called twice by PKFUN to fit the photopeaks of the standard source spectra. On the first call the Gaussian is fitted over the channel range defined by  $B(1) \pm 6.0 * B(2)$ , but since Ge(Li) photopeaks are quite asymmetrical in comparison to those measured in NaI(Tl) spectrometry, the parameters determined on the first call are used as initial estimates for a second call. On the second call the photopeak is fitted with the Gaussian function from channel  $N1$  to channel  $B(1) + 6.0 * B(2)$ .  $N1$  is taken as the lowest count channel satisfying,  $N(0.8H) \geq N1 < B(1)$ , where

$N(0.8H)$  defines the channel  $< B(1)$  containing  $\geq 80\%$  of the count in channel  $B(1)$ . In this manner the photopeak is systematically fitted with a Gaussian over the relatively symmetrically upper two-thirds of its extent. Appendix V shows sample residual counts for a number of the standard spectra after subtraction of the fitted Gaussian. The value of the count  $H$ , in the integer- $B(1)$  channel is indicated. The residual can be seen to be relatively consistent, especially in view of the limited number of photopeak channels over which the measurements were made.

Subprogram STDFT3 carries out the non-linear regression of the photopeak function. The logic of this subprogram is very similar to that of subprogram STDFIT, described in reference (4). The theoretical logic of STDFIT is given in Appendix VI; it is directly reproduced from reference (2) and is generally applicable to STDFT3. There are two major differences between the STDFIT and STDFT3 codes, the former is designed for a single Gaussian whereas STDFT3 is designed for  $n$ -Gaussians, although it is presently only 'DIMENSIONED' for two. The second major difference is that whereas STDFIT calls FUNUS to compute the photopeak function  $f(x_i)$  to be fitted to the photopeak counts  $y(x_i)$ , STDFT3 calls FUNZ to determine  $F(x_i)$ , a histogram, where  $x_i$  is the mid-channel pulse-height and

$$F(x_i) = \int_{x_i - 0.5}^{x_i + 0.5} f(v) dv, \quad (4)$$

$$\approx \sum_{j=1}^m f(v_j) \Delta v, \quad (5)$$

where

$v$  = pulse-height variable of integration for channel  $x_1$ ;

$m$  = number of subdivisions of channel  $x_1$

The above approach is necessary for Ge(Li) photopeaks because of the superior resolution as compared to NaI(Tl). A comparison of experimental and fitted photopeak distributions are given in Appendix VI.

#### 2.2.2.4 Compton Continuum Interpolation

Subprogram POGELI quadratically interpolates or extrapolates normalized Compton continua. It is called by RESFUN for response matrix vector generation purposes and multipeak standard spectrum analysis. Actual quadratic interpolation is performed by function subprogram TE. For energies between zero and that of the lowest energy input standard, the interpolation is necessarily linear. The linear interpolation assumes, reasonably, that at zero energy the channel counts are also zero.

Although the interpolation is quadratic, the redistribution of the standards before and after interpolation is such that the method developed here is referred to as one of 'parts'. While code CUPED uses the 'method-of-three-parts' <sup>(11)</sup>, CUGEL uses the 'method-of-two-parts'. This method divides the continuum into two characteristic regions: A) zero energy to Compton edge, and B) Compton edge to photopeak mean pulse-height. The mutual boundary of each region is overlapped for continuity reasons. The dashed curves in Figure 3 indicates the regional boundaries.

The major difference between the CUGEL and CUPED methods is in the handling of the backscatter peak, which is smaller but sharper in Ge(Li) than its counterpart in NaI(Tl). In code CUGEL, the backscatter peaks

are subtracted from the main continuum, normalized and interpolated separately. The subtraction is done in subprogram FITLIN which is called by subprogram BS. The normalization is carried out in BS with respect to the standard of lowest energy; the interpolation is carried out in BBS. Where backscatter peaks are merged with the Compton edge, as in the case of  $\text{Hg}^{203}$ , a backscatter peak is interpolated and subtracted in subprogram BS to leave an unmasked Compton edge. Figure 6 shows the backscatter and Compton edge peak pulse-height as a function of photon energy. The merged-region is clearly seen in this figure to be defined as  $0.24 < E < 0.34$ , MeV.

Prior to interpolation (or extrapolation) the continuum regions A and B are aligned such that the regional boundaries on which the Compton edges lie are at the same pulse-height. Alignment is carried out with respect to the continuum of highest energy for the set of three standards in the quadratic, by the calling of subprogram GANE. The two interpolated components, A and B, are unaligned by gain changing to obtain the desired continuum. The pulse-height axis direction of region B is reversed for convenience during the whole operation, i.e. zero pulse-height is taken at the photopeak mean pulse-height. An empirically modified form of the Compton angular-energy relationship is used to aid in automatically locating the Compton edges and backscatter peaks.

POGELI returns the interpolated Compton continuum to the calling program, RESFUN. Figure 3 shows example Compton continua as determined by CUGEL; they can be seen to compare well with the normalized continua from which they were determined. The photofractions of Figure 4 also substantiate the interpolated continua.

### 2.2.3 Analysis of Monoenergetic Spectral Contributions

Subprogram DISCRT is called by MAIN according to an input option to analyze photopeaks and their associated Compton continua, in complex spectral distributions. Subprogram DISCRT will fit a 'single or double Gaussian-plus-straight-line' function to the photopeaks of a multipeak spectrum. It will subtract the fitted photopeaks and their associated continua to leave a residual continuous spectrum. In the case of no continuous component in the complex spectrum, the residual will, ideally, have zero intensity.

The code CUGEL user may optionally input either the energy of the photopeaks to be fitted in DISCRT, the photopeak fitting limits (channel numbers), request the code to search for peaks or alternately combine these three options. In the event that the energies of only certain peaks are known they may be input, while the remainder may be defined by fitting limits. The choice of energy order of monoenergetic peak analysis and spectral stripping is left to the user; the code permits a mixed order to be chosen.

In addition to fitting and subtracting the monoenergetic components of an unknown spectrum, DISCRT determines their corresponding efficiency-corrected detector-incident photon number. The thus determined photon number may be, optionally, either added to the continuous photon number determined by later unfolding or diverted for separate output. In this way the separated radiations can be studied, e.g. bremsstrahlung analyses may be carried out even though the subject source also emits monoenergetic photons.

Subprogram DISCRT begins execution by determining whether the photopeak fitting limits have been input to MAIN by the user or whether they are to be calculated. In the event that they are to be calculated, DISCRT begins execution by estimating their channel locations based on the peak input



energies. It first establishes the approximate channel region of the photopeak. It then ascertains it more accurately for the approximated channel region by calling subprogram VECTMX to establish the channel of maximum count. The fitting limits are determined as a function of the photon energy dependent standard deviation. In the event that neither peak limits nor energies are input, DISCRT calls subprogram FIND to search for photopeaks. A check is made to ensure that all the limits determined are within the spectrum and that their domains do not overlap each other.

Subroutine FIND searches for peaks from channel MS to MX, excepting those channel regions where limits have been input. It will not examine spectral regions where the count is  $< G$ . The logic of FIND consists of testing the count  $y_i$  in channel  $i$  against the count in channels  $i - 1$  and  $i + 1$ , between channels  $N1$  and  $N2$ , where  $N2 = N1 + II$ ;  $II = 4$  was found to work satisfactorily for all spectra tested. A peak is assumed if

$$Y_{N1} + T * Y_{N1}^{1/2} < Y_i > Y_{N2} + T * Y_{N2}^{1/2} ; N1 < i < N2, \quad (6)$$

where

$T = 6$  to  $10$  and  $G = 100.0$ , were found to work satisfactorily for all spectra tested.

With the fitting limits established a single or double Gaussian distribution is regression fitted to each photopeak in turn providing the number of channels in the peak is greater than six. Actual photopeak function fitting is carried out by the calling of subprogram PKFUN. In the case of double or merged peaks, subprogram GUESS3 is called to estimate initial values of the Gaussian parameters. GUESS3 estimating is carried out using the general logic described in Section 2.2.2.3 for PKFUN.

In the event that the photopeak is distributed over six or less channels, the area and mean pulse-height are determined from the counts in excess

of a straight line joining the counts in the limit channels and from the first moment of rotation, respectively.

The Compton continuum associated with each photopeak is determined by DISCRT calling subprogram RESFUN, which returns an interpolated continuum normalized with respect to a photopeak of unit area and pulse-height (NORM channels). The continuum is then scaled and gain changed according to the determined peak area and pulse-height.

Gain changing is carried out through DISCRT calling subprogram GANE. The photopeak and Compton continuum are then subtracted from the unknown spectrum for each monoenergetic spectral component in turn to finally leave a continuous residual spectrum. If no continuous contribution was present in the unknown, then ideally a zero spectrum will result.

Prior to returning the residual continua to MAIN for iterative unfolding, DISCRT determines the photon number corresponding to each monoenergetic spectral component. This is done by computing the photofraction,  $P(E)$ , the detector interaction efficiency,  $\epsilon(E)$ , and the attenuation term for air and other material interposed between the source and detector,  $k(E)$ . The photon number is then determined from the relationship:

$$N(E) = \frac{\text{Photopeak Area (or Counts)}}{P(E) \cdot \eta(E)} \quad (7)$$

where

$$\eta(E) = \epsilon(E) \cdot k(E).$$

The corrections noted are carried out by subprogram DISCRT calling subprogram DETECT. N(E) is returned to MAIN to be optionally either added to the iteratively unfolded continuum number spectrum or to be output separately.

#### 2.2.4 Spectral Unfolding

The reduction of pulse-height analyzer continuous spectra to photon number spectra and the application of efficiency corrections are carried out under the control of subprogram SØLN called by the main program. Subprogram SØLN begins execution by carrying out certain initializations after which it calls subprogram RESMAT to unfold the pulse-height analyzer spectra according to the Scofield method<sup>(2,5,6)</sup>. The number spectra returned by subprogram RESMAT are corrected for efficiency by SØLN calling DETECT. The thus corrected number spectra are returned to MAIN. The remainder of this section describes the logic of the unfolding subprogram RESMAT and of the efficiency vector subprogram DETECT, AIRABS and ALUM.

Subprogram RESMAT unfolds the pulse-height analyzer spectra by solving the matrix equation (in matrix notation)

$$\vec{P} = \vec{R} \vec{N} \quad (8)$$

where  $\vec{P}$  and  $\vec{N}$  are the m-dimensional vectors of the PHA spectrum and the efficiency uncorrected photon number spectrum, respectively, and  $\vec{R}$  is the m x m square response function matrix. Equation (8) is formally solved

as

$$\vec{N}' = \bar{\bar{R}}^{-1} \vec{N} \quad (9)$$

where  $\bar{\bar{R}}$  is non-singular and  $\bar{\bar{R}}^{-1}$  is its inverse. Subprogram RESMAT executes equation (9) iteratively according to the Scofield method<sup>(5,6)</sup>. Figure 7 shows a flow diagram of the iterative algorithm coded in subprogram RESMAT. Further details are referred to references (1-8).

The efficiency corrected photon number spectrum  $N$ , is determined from equation (9), as<sup>(2)</sup>

$$\vec{N} = \bar{\bar{\eta}}^{-1} \vec{N}' \quad (10)$$

where  $\bar{\bar{\eta}}$  is a diagonal efficiency matrix accounting for interaction efficiency and photon attenuation by detector cladding, air and aluminum interposed between the source and the detector active region. Subprogram SØLN calls subprogram DETECT which in turn calls function subprograms EFFIC2, AIRABS and ALUM, to determine  $\bar{\bar{\eta}}$ . SØLN then executes equation (10) and returns the determined photon number spectrum to MAIN. Figure 8 shows an example spectrum before ( $\vec{P}$ ) and after ( $\vec{N}$ ) unfolding.

Subprogram EFFIC2 determines the interaction efficiency for the right-cylindrical Ge(Li) detector exposed to an axially located source of photons of energy  $E$ , as<sup>(2,12)</sup>

$$\epsilon(E, r) = \frac{1}{\Omega} \int_{\text{detector}} (1 - e^{-u(E)x}) d\Omega \quad (11)$$

where

$\mu(E)$  = total linear attenuation coefficient of Ge(Li) for photons of energy  $E$  (excluding coherent scattering)<sup>(13-17)</sup>,

$x$  = photon vector path length in the detector prior to interaction,

$r$  = source-to-detector distance,

$\Omega$  = the solid angle subtended at the source by the detector.

Equation (11) may be rewritten in a form more suitable for solution, as <sup>(2,18)</sup>

$$\epsilon(E, r) = \underbrace{\int_0^{\alpha_1} \left[ 1 - e^{-\mu(E) H \sec \alpha} \right] \sin \alpha \, d\alpha}_{\text{---}} + \underbrace{\int_{\alpha_1}^{\alpha_2} \left[ 1 - e^{-\mu(E) (R_x \csc \alpha - r \sec \alpha)} \right] \sin \alpha \, d\alpha}_{\text{---}} \quad (12)$$

$$\underbrace{\int_0^{\alpha_1} \sin \alpha \, d\alpha + \int_{\alpha_1}^{\alpha_2} \sin \alpha \, d\alpha}_{\text{---}}$$

where

$$\alpha_1 = \tan^{-1} \left( \frac{R_x}{r + H} \right)$$

$$\alpha_2 = \tan^{-1} \left( \frac{R_x}{r} \right)$$

$H$  = cylindrical length of Ge(Li) detector active region

$R_x$  = cylindrical radius of Ge(Li) detector active region

The geometry for equation (12) is given in Figure 9.

In practice the source will have finite dimensions, but as long as they are relatively small, equation (12) is valid. The interaction efficiency

for small line and disc sources relative to a point source may be estimated from reference (17). Equation (12) is evaluated by a numerical integration, which is carried out by subprogram SIMPSN, which calls function FC to determine the integrand. The photon flux incident on the crystal is corrected for air and aluminum absorption. This correction, multiplied by Equation (12), yields the diagonal efficiency-matrix  $\eta$ , as

$$\eta_{ij} = \epsilon(E_i, r) \exp(-r \mu_{\text{air}}(E_i)) \cdot \exp(-l \cdot \mu_{\text{alum}}(E_i));$$

$$i = j = 1, 2, \dots, m, \quad (13)$$

where

$\mu(E)$  = total linear attenuation coefficient of the material (air and aluminum per subscripts) interposed between source and detector for photons of energy  $E_i$ ,<sup>(13-17)</sup>

$l$  = thickness of the aluminum absorber material interposed between source and Ge(Li) detector, active region

$m$  = matrix size.

In accord with input option signal  $m(19) \neq 0$ , the interactions efficiency given by Equations (12) and (13) may be bypassed and instead obtained from an empirical relationship as<sup>(19)</sup>

$$\epsilon(E) = 0.441 E^{-1.32} / P(E), \quad (14)$$

The agreement between this equation and equation is seen in Figure 10.

### 2.2.5 Analysis of Unfolded Spectra

Subprogram GEØMTR is called by MAIN to carry out a final analysis on the unfolded photon number spectra. The spectra are corrected for primary source decay and converted by GEØMTR to differential photon number flux at the detector per unit time,  $N_x(E)$ , (coded as PHI), as

$$N_x(E) = \frac{N(E)}{\pi R_x^2}, \text{ } \gamma/\text{cm}^2 \text{ sec} \quad (15)$$

where

$R_x$  = Ge(Li) crystal radius, cm.

The differential energy flux incident on the crystal per unit time,  $I_x(E)$ , (codes as ENXTAL), is determined as

$$I_x(E) = N_x(E) \cdot E, \text{ MeV/cm}^2 \text{ sec} \quad (16)$$

The energy integrated exposure dose rate at the crystal,  $D$ , (coded as DOSDET), is determined as

$$D = \int_{\text{energy}} N_x(E) E \mu_{\text{air}}(E) K dE, \text{ roentgens/hours} \quad (17)$$

where

$\mu_{\text{air}}(E)$  = energy mass absorption coefficient of air,  $\text{cm}^2/\text{gm}$

$K$  = conversion constant

$= 3600/5.24 \times 10^7, \text{ (roentgens-second-gm air)/MeV-hour}$

The integration in equation (17) is carried out numerically by GEØMTR, as

$$D = \sum_{i=1}^m N(E_i) E_i \mu_{\text{air}}(E_i) K \Delta E_i, \quad (18)$$

The energy integrated photon number and photon energy flux at the crystal is determined by integrating  $N_x(E)$  and  $I_x(E)$  over  $E$ , (coded as SUMNUM and SUMENY); the units are  $\gamma/\text{cm}^2\text{-sec}$  and  $\text{MeV}/\text{cm}^2\text{-sec}$ . The following tabulated data are also determined by subprogram GEOMTR for output by the calling main program:

<u>FORTTRAN NAME</u>	<u>EQUAL TO</u>	<u>DEFINITION &amp; UNITS</u>
(AT THE CRYSTAL)		
AVENGY	$\frac{\sum N(E) \cdot E \Delta E}{\sum N(E) \cdot \Delta E}$	average energy, MeV
PHNUBE	$\frac{\sum N(E) \cdot \Delta E}{N_{\beta}}$	integrated photon number flux per beta source strength, $(\gamma/\text{cm}^2\text{-sec})/(\beta/\text{sec})/\text{MeV}$ ; ( $N_{\beta}$ defined below)*
ENBENY	$\frac{\sum N(E) \cdot E \cdot \Delta E}{E_{\beta \max}}$	integrated energy flux per beta maximum energy, $(\text{MeV}/\text{cm}^2\text{-sec})/\text{MeV}$ ; ( $E_{\beta \max}$ defined below)*
PHENBE	$\frac{\sum N(E) \cdot \Delta E}{N_{\beta}}$	integrated energy flux per beta source strength, $(\text{MeV}/\text{cm}^2\text{-sec})/(\beta/\text{sec})$ *
DOXBEX	$D/N_{\beta}$	dose rate per beta source strength, $(\text{r/hr})/(\beta/\text{sec})$ ; (D defined in equation 13))*
(AT THE SOURCE)		
DOSCYL	$\frac{\text{DOSBEX}}{G}$	dose rate per beta source strength, $(\text{r/hr})/(\beta/\text{sec})$ ; (G defined below)*

\*Beta,  $N_{\beta_A}$  and  $E_{\beta \max}$  are used in this section because of earlier bremsstrahlung analyses; gamma ( $\gamma$ ) may be the substituted meaning where it applies.



DCYVOL

DOSCYL  
Source Volume

dose rate per beta source  
strength per  $\text{cm}^3$  of source  
volume, =  $\text{DOSCYL}/\text{cm}^3$

where

$E_{\beta_{\max}}$  = maximum beta (or chosen  $\gamma$ ) energy in MeV

= EBMAX of card (6) of report section 3.2\*

$N_{\beta}$  = number of source emitted betas or  $\gamma$ 's per  
unit time

= (SBETA of card (6) of report section 3.2)  
 $\div 3.7 \times 10^{10}.$ \*\*

and

(19)

$$G = \Omega_x / \Omega = 1/2(1 - r/(r^2 + R_x^2)^{1/2})$$

where

$\Omega_x$  = solid-angle subtended by the crystal at the source  
geometric center,

$\Omega$  = total solid-angle at the source =  $4\pi$  steradian

$r$  = source to crystal distance.

Subprogram GEOMTR returns all of the above data to the main program for  
output.

\* if not meaningful to code user, then input as, EBMAX = 1.0

\*\* if not meaningful to code user, then input as, SBETA =  $1.0/(3.7 \times 10^{10})$ .

### 2.3 Code Constants

In this section the origin and meaning of certain constants coded into CUGEL, are discussed. The discussion is carried through in alphabetic order of subprograms, except for General Discussion and MAIN which are presented first. Certain subprograms require no discussion.

General Discussions: Certain constant values appear periodically throughout CUGEL. The values 2.35482, 2354.82, 0.3989423 and 1.065 are Gaussian or normal distribution constants<sup>(20)</sup>. The values 60 (minutes/hr and seconds/min) and 1440 (minutes/day) are clock time conversion constants. Other values are either obvious (e.g.  $\pi = 3.14159265$ ) or constants unique to the code logic except as explained below.

MAIN: Certain constants required by CUGEL subprograms are coded in MAIN and communicated by COMMON/CNSTNT/. The constant TKLUM is the thickness of aluminum absorber in front of the Ge(Li) detector; it is presently coded as 0.9 cm for subprogram ALUM. The constants T 20 = 20.0, T 50 = 50.0 and T 01 = .0001 are used by the code if input (ØN, HITMAX, EPS) left blank; this is discussed in Section 3.2. The constant T 1293 = 0.001293 is the density of air coded for subprogram AIRABS. The constants T 90 = 900000. and T100 = 1000000. are used by subprograms DEC and RESFUN for checking for spectral counts in the complement mode. The constants associated with UT at statement numbers 40 to 47 are explained in Section 3.2. The constant 3.7 E + 10 at statement number 128 + 1 is the conversion factor for Curies to disintegrations/second. IFIFTY = 50, is the maximum number of photopeaks allowed in the unknown spectrum. TEN and IFØUR = 10. and 4 are T and G of equation (6). T06 =  $10^{-6}$ , is the integration criterion for function SIMPSN. NØRM = 200, is continuum pulse-height normalizing constant for RESFUN. NLI = 800 and NLIMIT = 400 are related to allowed vector dimensions.

EFFIC2: The total (less coherent scattering) linear attenuation coefficients for Ge(Li) in  $\text{cm}^{-1}$  are stored in the R DATA Statement;<sup>(16)</sup> the corresponding energies are stored in the X DATA Statement. Ge(Li) density was taken as 5.32 gm/cc.

ALUM: The total linear attenuation coefficients of aluminum in  $\text{cm}^{-1}$ , are stored in the R DATA Statement;<sup>(18)</sup> the corresponding energies are stored in the X DATA Statement.

FITLIN: The constants 5, .5, and 12.0 are associated with the fitting of a straight line base under the backscatter peak based on the six channels on either side of the defined peak region.

AIRABS: The mass absorption coefficients of air are given in the A DATA statement in  $\text{cm}^2/\text{gm}$ .<sup>(13)</sup> The coefficients include coherent scattering; the corresponding energies are stored in the X DATA statement. They are multiplied by the density of air (T 1293) in gm/cc to give output units in  $\text{cm}^{-1}$ .

DØSE: The energy mass absorption coefficients for air are given as R in the DATA statement in  $\text{cm}^2/\text{gm}$ .<sup>(13)</sup> They are based at 20°C and a fractional weight composition of

Nitrogen	0.755
Oxygen	0.232
Argon	0.013

The energies corresponding to R are given the X DATA statement.

GEØMRT: The constant defined as CØNST has been already discussed for Equation (17).

STDFT3: The constant  $EPS = .00001$  (at statement 100 - 3), is the fitting criterion for the photopeak non-linear regression. The constant  $NI = 10$  is a stopping criterion for non-linear regression in the event of a non-convergence.

DISCRT: The product of the constants 1.2 and 0.00128 has been defined as 0.001536 in Equation (2); the constant 0.395 has also been defined in Equation (2).

DECAY: The constant 1440 = the number of minutes in 24 hours.

SIMPSN:  $TMAX = 2048$  is the maximum allowable number of integration increments.

RESFUN: The constants 0.75, 0.85, 0.80, 0.85, 178./200. and 105./200 are general empirical values associated with analyzing of the JPL  $Co^{60}$  standard spectrum supplied; they may be interpreted as fraction of photopeak pulse-height.

BS: The equation expressed by Statement 61, is for smoothening the standard spectrum in the region below the backscatter peak, when  $E > 0.34$  Mev; the constants were derived from the JPL standard spectra. The equation expressed by Statement 62 + 1 allows the backscatter peak to be normalized with respect to the lowest input standard even though the backscatter peak may be merged with the Compton edge; the constants were derived from the JPL standard spectra. The constants 0.875 and 1.16 at Statement 70 + 4 and 70 + 5 were derived from the JPL standard spectra to define the backscatter peak region for analysis in the Compton edge merging region, 0.24 to 0.34 Mev.

### 3. CODE OPERATING INFORMATION

#### 3.1 GENERAL

Code CUGEL is written in a generalized FORTRAN-V for the UNIVAC-1108. It may be readily run on other computers with sufficient core size; i.e., the present version requires ~ 50K words. There are no Sense Switch or special tape requirements. Input formats are standard FORTRAN-IV or V, as given in any UNIVAC, IBM, or CDC FORTRAN manual; the code has been designed with a view to ease of translation for use on other computers. Input/output tapes are presently coded as LI and LØ equal to 5 and 6, respectively, at the beginning of MAIN (statement 2602 + 5 and + 6). A code listing is given in Appendix II.

Figure 11 shows a general arrangement for the data input cards. Input card details, order, formats, restrictions and location are given in Section 3.2. Card numbers are encircled and defined in the order in which they are read by the code. A sample input listing is presented in Appendix III.

The code CUGEL input data card deck consists of twelve (12) types of cards, referred to as Card ①, Card ②, etc. If the type requires more than a single card, the reference is made to Card Set ○. Card ① is a single card, input only once. Cards ② ③ and ④ are single cards input at least once. Card set ⑤ ( ⑤A or ⑤B ) is input at least once in order to define the response matrix. If the user only wishes to generate a response matrix but not to apply it to any data, then no further input is required. If the matrix is to be applied to analyze unknown spectra, further input is required to define the spectral data and the required analysis.

Card set ⑥ consists of two cards which must be input to define parameters which are common to all PHA spectra in the PHA spectral data set (card set ⑫), e.g., source size, counting time, source strength, etc. Card set ⑦ must be input to define parameters unique to each PHA spectrum in the PHA spectral data set, e.g., zero shift required, subtract background or not, source-to-detector distance, energy calibration data, etc. Card ⑧ and card sets ⑨ through ⑪ are optional. Card set ⑫ consists of the unknown PHA-spectra to be analyzed and their PHA-background-spectra. The code will analyze spectra of up to 400 channels, although up to 1000 channels may be input and code gain-changed to 400 for analysis.

The optional cards are as follows: Card ⑧ is a single card to allow the user to study the iterative unfolding convergence, i.e., intermediate unfolding data is output. Card set ⑨ allows the user to replace undesirable peaks, prominences or spurious spectral counts with a straight-line shape. Card set ⑨ also allows the user to load initial spectral channels with a straight-line shape. Card set ⑩ allows the user to input the energy of photopeaks to be analyzed. Card set ⑪ allows the user to input the channel region of photopeaks to be analyzed. The input of both card set ⑩ and ⑪ allows the user to give the energy of certain peaks and the channel region of others. Card set ⑪ allows the user to input energy as well as channel domain for peaks, in which case the code will use the input energy as opposed to the code determined energy for such as efficiency calculations. This last is useful in applications where a prior knowledge indicates that the energy which the code would determine might not be precise.

The input of channel number values must be as recorded by the pulse-height analyzer. The code will change the input values in accord with requested shifts or gain changes. In Section 3.2, 'rounded-up' refers to the 'next highest integer value', i.e., 3.7 rounded-up is 4. The input order of card

sets ⑦ , ⑨ , ⑩ , ⑪ , and ⑫ must correspond to the spectra of card set ⑫ .

The code output is reviewed in Section 3.3. Appendix IV is a sample output listing. It corresponds to sample input of Appendix III. Debug type output may be obtained by input of  $M(8) = 8$  on card ③ . The user is cautioned with respect to profusion of output under this option - - - a trial using sample data is recommended first.

### 3.2 Card Input Details

Card ① (one card; once only)

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
SET	1-10	F10.5	Total number of spectra to be unfolded by a code run (see index KK in Figure 2)

Card ② (single card)

CASE	2-72 (column 1 for printer control)	A	User's problem description (alphanumeric)
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Card ③ (single card) (See Figures 2 and 12 for additional M(I) details)

M (1)	1-3	I3	Signal for routing after response matrix generation > 0 CALL EXIT = 0 Continue < 0 Return to READ card ②
M (2)	4-6	I3	= 0, use existing response matrix ≠ 0, generate new response matrix using existing standard spectra
M (3)	7-9	I3	If ≠ 0, read card ⑧ (iterative unfolding output signal)
M (4)	10-12	I3	If ≠ 0, read card set ⑨ (replace peak with straight line and/or "fill-in" initial NFILL channels)
M (5)	13-15	I3	If ≠ 0, by-pass RESMAT (unfolding) in subprogram SØLN (See Figure 12)
M (6)	16-18	I3	If ≠ 0, add photopeak contributions to iteratively unfolded continuous photon number spectrum
M (7)	19-21	I3	If ≠ 0, DISCRT called for monoenergetic contribution analysis.
M (8)	22-24	I3	Intermediate output (for debugging) if ≠ 0
M (9)	25-27	I3	If ≠ 0, the monoenergetic contributions determined by DISCRT are converted to photon flux, and output but they are not added to the unfolded flu



<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
M (10)	28-30	I3	If $\neq 0$ , subprograms DETECT and SØLN are bypassed in MAIN. (See Figure 2)
M (11)	31-33	I3	If $\neq 0$ , the unknown spectrum is corrected for interaction efficiency before pulse-height gain change reduction (See Figure 2)
M (12)	34-36	I3	If = 0, call GANE before iterative unfolding (See Figure 2)
M (13)	37-39	I3	If 0, by-pass SØLN (See Figure 2)
M (14)	40-42	I3	If $\neq 0$ , by-pass DETECT (efficiency) in subprogram SØLN (See Figure 12)
M (15)	43-45	I3	If $\neq 0$ , assume efficiency vector elements = unity in subprogram SØLN (See Figure 12)
M (16)	46-48	I3	If $\neq 0$ , do <u>not</u> correct for source decay, i.e., assume decay factor = 1.0
M (17)	49-51	I3	If $\neq 0$ , output the PHA spectrum
M (18)	52-54	I3	If $\neq 0$ , bypass final result computations, i.e., bypass GEØMTR
M (19)	55-57	I3	If $\neq 0$ , Equation (14) used instead of equation (13).

NOTE: The choice of non-zero values required for M (I) is arbitrary, however, actual subscript index values will aid in identity, e.g., if M (7)  $\neq 0$  then input as = 7. Options M(19) to M(24) are spare.

Card ④ (single card; last 5 variables may be blank)

ELIMIT	1-10	F10.5	The energy of the upper edge of the response matrix highest channel (MeV); should correspond to unknown spectra to be analyzed. e.g. if unknown 400 channel spectrum has 2.615 MeV calibrating peak in channel 380, then $ELIMIT = (400/380) * 2.615$ = 2.753 MeV
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<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
ØJSØ	11-20	F10.5	Loop limit; number of sets of source data (card sets (7) through (8), except (8), before loopback to READ card (2).
ØMM	21-30	F10.5	If < 0 READ a response matrix, (card set 5B ), = 0 use already computed matrix. > 0 generate new matrix; call RESFUN. Choice of values are arbitrary, e.g. -1. and +1.
ØN	31-40	F10.5	The size of the response matrix, i.e. number of channels; also the size of final flux spectra, ≤ 40.0.
HITMAX	41-50	F10.5	The maximum number of unfolding iterations; an even number such as 50.0 unless iterating output per M (3) required. ≤ 100.0.
EPS	51-60	F10.5	Convergence tolerance at which iteration will cease. e.g. .0001.
RX	61-66	F6.4	Radius of Ge(Li) active region (cm).
H	67-72	F6.4	Cylindrical length of Ge(Li) active region (cm).

NOTE: RX and H set equal to 1.63 and 3.1, respectively in two statements following read statement (in MAIN); if other values to be input, remove these statements.

Also,

Card (5)

Card 5 refers to a deck of cards of which two kinds are allowable, namely: (5A) or (5B).

Card set (5A) to be input, if ØMM > 0 (read by subprogram RESFUN to generate a response matrix).

NAME	COLUMN	FORMAT	DESCRIPTION, PURPOSE OR USE
------	--------	--------	-----------------------------

Card Set (5B) to be input if  $\emptyset\text{MM} < 0$  (response matrix input to program MAIN).

Neither set to be input if  $\emptyset\text{MM} = 0$ , i.e. a correct response matrix is assumed as existing in storage.

Card Set (5A) (Standard source spectra and associated parameters)

Card (5A) - 1 (single card) (See Figure 4)

NSTAND	1-5	I5	The number of standard source spectra.
NXLIM	6-10	I5	Number of channels in each standard spectrum.
NADD	11-15	I5	The number of standard spectra with energy, STDEN (J, 1) 1.33 MeV

Card Set (5A) - 2.1 (Single card preceding each spectrum) (See Appendix III)

ALABEL (I), BLABEL (I)	2-6	2A3	Standard source identity; user choice e.g. CS137.
STDEN (J, 1)	11-20	F10.5	Energy corresponding to standard source spectrum photopeak (MeV) (highest energy if two peaks, e.g. 1.33 for Co <sup>60</sup> and 1.114 for Zn <sup>65</sup> ).
STDEN (J, 2)	21-30	F10.5	Energy corresponding to standard source spectrum photopeak (MeV) (lowest energy if two peaks, e.g. 1.17 for Co <sup>60</sup> and 0.511 for Zn <sup>65</sup> ).
SHIFT (I)	31-40	F10.5	The channel location ( $\pm$ ) of the standard spectrum true zero pulse-height. The code carries out a shift correction.
MENSJ	41-45	I5	Approximate mean pulse-height of standard source spectrum photopeak corresponding to STDEN (J, 1) (channel)
MS $\emptyset$	46-50	I5	Atomic number corresponding to standard source spectrum (e.g. 60 for Co <sup>60</sup> and 203 for Hg <sup>203</sup> ).

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
MSXJ	51-55	I5	Replace region from channel MSXJ to MFXJ with straight line, e.g. use for removal of 0.073 MeV Hg <sup>203</sup> X-ray (channel).
MFXJ	56-60	I5	Replace region from channel MSXJ to MFXJ with straight line, e.g. use for removal of 0.073 MeV Hg <sup>203</sup> X-ray (channel).
MENCS	61-65	I5	Replace initial ENCS + 1 (channel).
<u>Card Set (5A) - 2.2</u> (NXLIM/10 (rounded-up) cards); (See Appendix III)			
R (1, 1)	1-7	F7.1	The count in the first channel of the first input standard spectrum.
R (2, 1)	8-14	F7.1	The count in the second channel of the first input standard spectrum.
.			
.			
R (10, 1)	63-70	F7.1	The count in the tenth channel of the first input standard spectrum.
R (11, 1)	1-7	F7.1	The count in the eleventh channel of the first input standard spectrum.
.			
.			
R (NXLIM, 1)	-	F7.1	The count in the MXLIMth channel of the first input standard spectrum.

NOTE: Repeat Card (5A) - 2.1 and Card Set (5A) - 2.2 for each standard source spectrum i.e. NSTAND times; the lowest energy standard must be input first and the remainder must be in energy ascending order (with respect to STDEN (J, 1)).

Card Set (5B) (Response matrix)

Card Set (5B) - 1 ((ØN x ØN/5) Cards); ((R(J, I), I = 1, ØN), J = 1, ØN)

R (1, 1)	1-11	E11.4	Response Matrix Element 1, 1
R (1, 2)	12-22	E11.4	" " " " 1, 2

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
R (1, 3)	23-33	E11.4	Response Matrix Element 1, 3
R (1, 4)	34-44	E11.4	" " " " 1, 4
R (1, 5)	45-55	E11.4	" " " " 1, 5
R (1, 6)	1-11 (second card)	E11.4	" " " " 1, 6

R (ØN, ØN) 45-55 E11.4 " " " " ØN, ØN

NOTE: The first ØN elements input represent the lowest energy matrix vector spectrum (analogous to a PHA spectrum); similarly, the second ØN elements, etc. The sum over each vector must = unity.

Card (5B) -2 (single card)

NSTAND	1-10	I10	Number of cards in 5B -3.
K	11-20	I10	Index of first non-zero increment in response matrix.

Card Set (5B) -3 (NSTAND cards)

(Photopeak calibration energies, pulse-heights and standard deviations e.g. from a previous RESFUN output.)

STDEN (1,1)	1-10	F10.5	First calibration energy (MeV).
PARAV (1,1)	11-20	F10.5	First calibration photopeak pulse-height (channels).
PARAS (1,1)	21-30	F10.5	First calibration photopeak Gaussian standard deviation (channels).
STDEN (NSTAND, 1)	1-10	F10.5	NSTAND calibration energy (MeV).
PARAV (NSTAND, 1)	11-20	F10.5	NSTAND calibration photopeak pulse-height (channels).
PARAS (NSTAND, 1)	21-30	F10.5	NSTAND calibration photopeak Gaussian standard deviation (channels).

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
<u>Card (6)</u> (two cards)			
<u>First Card:</u>			
BTAG, BTAGA	2-6	A4, A2	Unknown source identity (alphanumeric)
SBETA	11-20	F10.5	Unknown source strength (Curies); see page 27 footnote.
EBMAX	21-30	F10.5	Unknown source maximum or reference energy (MeV) (see page 27 footnote).
CYLDIA	31-40	F10.5	Unknown source cylindrical diameter (cm).
TH	41-50	F10.5	Unknown source half-life (optional units; see UT this card).
RUNS	51-60	F10.5	Number of spectra per unknown source data set, $\leq 20.0$ .
CHANLS	61-66	F6.0	Number of channels in unknown spectrum $\leq 400$ . If $> 400$ , use CHANLS = 400 and refer to MNX (See next card)
UT	67-72	F6.0	Multiplier for TH: UT = 0.0; TH in years = 1.0; TH in seconds = .60.0; TH in minutes = 24.0; TH in hours = 365.0; TH in days (Values other than these will cause output of error flag followed by CALL EXT)

Second Card:

M222	1-5	I5	The number of peaks to be fitted with a Gaussian for which channel limits must be input (per card set (11) $\geq 20$ -M66; See card set (10) note.
M66	6-10	I5	The number of peaks to be fitted with a Gaussian for which only the energy is to be input (per card set (10) $\geq 20$ -M22.

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
MZ	11-15	I5	The number of channels, in each unknown spectrum, which are to be loaded with zero counts (beginning at channel 1).
MNX	16-20	I5	Unknown spectra of MNX channels may be input to code
MBX	21-25	I5	Same as MNX, except that it refers to background spectra.
MSM	26-30	I5	If $\neq 0$ , smooth spectra before analysis; use 1.0 or 2.0 for single or double smoothing pass by subprogram GANE.
MS	31-35	I5	Subroutine FIND will "search" for peaks from channel MS to MX.
MX	35-40	I5	Subroutine FIND will "search" for peaks from channel MS to MX.

NOTE: BTAG/BTAGA, SBETA and EBMAY may be 'blank', 1.0 and 1.0 respectively, if not known prior to analysis. Actual values are used only for normalizing in subprogram GEOMTR prior to output of analysis results; see page 27 footnote.

#### Card Set ⑦

"Number of cards in set ⑦" = RUNS. Input of card I = 1 detailed below, cards 2 to RUNS similar. Card order must correspond to related pulse-height analyzer unknown spectra,  $I \geq 20.0$ .

If number of channels in the unknown spectrum is  $> 400$  then specify the value as MNX and input CHANLS = 400 (see last card).

DOST (I)	1-10	F10.5	Distance from unknown source to front face of Ge(Li) active region (cm).
DELT (I)	11-20	F10.5	Live time counting duration for unknown spectrum (minutes).

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
TM1 (I)	21-30	F10.5	Time duration from reference time to start of counting (days).
TTZ (I)	31-40	F10.5	Pulse-height analyzer channel location of true zero pulse-height (channels).
BK (I)	41-50	F10.5	BK (I) times a background spectrum may be subtracted from the unknown spectrum (if BK (I) negative, then is added).
BNBK (I)	51-60	F10.5	Background spectrum signal: < 0 subtract previously stored background = 0 no background > 0 read and subtract background Background spectra are read following unknown spectra with which they are associated.

Card ⑧ (one card input if M (3)  $\neq$  0)

This card may contain up to 18 integer numbers to define the iterating or unfolding loop at which intermediate output is desired.  $\geq$  eighteen indices may be input. The card format is 18I4.

Example:

MN (1)	1-4	I4	Iterating loop index e.g. 3
MN (2)	5-8	I4	" " " e.g. 5
MN (3)	9-12	I4	" " " e.g. 9

will cause subprogram RESMAT to output on iterating loops 3, 5 and 9.

Card Set ⑨ (RUNS cards (rounded-up) to be input if M (4)  $\neq$  0)

NIX (1)	1-5	I5	Replace a peak (or other prominence in spectrum 1 of card set ⑫ with a straight line from channel N1X (1) to N2X (1); the count rate in M1X (1) and N2X (1) are used to determine the slope and intercept of a straight line replacement.
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<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
N2X (1)	6-10	I5	See above.
NFILL (1)	11-15	I5	Replace in unknown spectrum 1 of card set (12), channels 1 to (NFILL (1) -1) with a straight line of slope VAL (1) based on the count in channel NFILL (1).
VAL (1)	16-25	F10.5	Same as above.
N1X (2)	26-30	I5	Same as N1X (1) only for second spectrum.
N2X (2)	31-35	I5	Same as N2X (1) only for second spectrum.
NFILL (2)	36-40	I5	Same as NFILL (1) only for second spectrum.
VAL (2)	41-50	F10.5	Same as VAL (1) only for second spectrum.
.			
.			
.			
N1X (RUNS)	-	I5	Same as N1X (1); for spectrum RUNS.
N2X (RUNS)	-	I5	Same as N2X (1); for spectrum RUNS.
NFILL (RUNS)	-	I5	Same as NFILL (1); for spectrum RUNS.
VAL (RUNS)	-	F10.5	Same as VAL (1); for spectrum RUNS.

NOTE: VAL (9) would be the fourth and last field of fifth card for RUNS = 9; the number of cards ( $\geq 10$ ) depends on RUNS.

Card Set (10) (1 to 4 cards input if  $M6 \neq 0$ )

This card set is input only when  $M6 \neq 0$ . It must consist of  $M6/5$  (rounded-up) cards corresponding to the number of unknown energy-specified peaks in the card set (12) spectra. Each card contains  $\geq 5$  photopeak photon energies corresponding to the unknown complex-plus-continuous spectrum to be analyzed. From one to 20(= M222) photopeaks may be energy specified per spectrum i.e. a maximum of 4 cards per spectrum.

EU (1)	1-10	F10.5	Energy of the first energy specified photopeak in card set 12 spectra (MeV).
--------	------	-------	--

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
EU (2)	11-20	F10.5	Energy of the second energy-specified photopeak in card set 12 spectra (MeV).
EU (3)	21-30	F10.5	Similar to above.
...			
EU (M6)	-	F10.5	Similar to above.

NOTE: The first photopeak in each spectrum is that of lowest energy with the remainder being in energy ascending order. The user is cautioned that peak channels may also be input instead or in addition, per card set (11) if  $M22 \neq 0$ ;  $M22 + M6 \geq 20$ .

Card Set (11) (1\*RUNS to 7\* RUNS cards input if  $M22 \neq 0$ ) (See Figure 12).

This card set is input only when  $M22 \neq 0$ . It must consist of  $(M22/3)$  (rounded-up) cards corresponding to the number of unknown channel-limit specified spectral photopeaks in card set 12. Each card contains information for  $\geq 3$  photopeaks. The information advises the code of whether peak is a single peak or is instead one of a pair, of the upper and lower fitting limits (channels) and of the energy if it is not known.

NJ (1)	1-4	I4	Signal for first channel-limit-specified peak of set (12) spectra: = 1, if a single peak = 2, if one of two peaks in a pair.
NSS (1)	5-8	I4	Channel number defining fitting limit on low energy side of first channel-limit-specified peak, i.e. fit peak from channel NSS (1) to NFNN (1).
NFNN (1)	9-12	I4	Channel number defining fitting limit on high energy side of first channel-limit-specified peak, i.e. fit peak from channel NSS (1) to NFNN (1).
EU (1)	13-20	F8.4	Energy of first specified peak (MeV).

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
NJ (2)	21-24	I4	Similar to NJ (1).
EU (3)	53-60	F8.4	Similar to EU (1).
NJ (4)	1-4	I4	Similar to NJ (1).
EU (M22)	-	F8.4	Similar to EU (1).

NOTE: The user is cautioned that peak energy data may also be input instead or in addition, per card set (10) if  $M66 \neq 0$ ;  $M222 + M66 \geq 20$ . If  $M66 = 0$  and  $M222 \neq 0$  then photopeaks data may be input in any every order; if  $M66 \neq 0$  and  $M222 \neq 0$  then input is expected in energy ascending order. Where data is input for double peaks NJ (I) and NJ (I + 1) = 2 and 0, respectively, then energy ascending order is expected if (I and I + 1) = 2 and 3, is given:

<u>NJ (2)</u>	<u>NSS (2)</u>	<u>NFNN (2)</u>	<u>EU (2)</u>	<u>NJ (3)</u>	<u>NSS (3)</u>	<u>NFNN (3)</u>	<u>EU (3)</u>
2	46	-	0.501	0	7	66	0.575

This specifies that the code shall carry out a double peak analysis between channels 46 and 66, that peak energies are 0.501 and 0.575 MeV and that the peaks are approximately 7 channels apart. The code analysis will determine the actual separation distance and thus 7 is given only as an estimate.

#### Card Set (12)

The number of cards in this set =  $(\text{CHANLS} * \text{RUNS} / 10.0 + \text{the number of background cards if any}) * \text{The cards will contain the unknown source spectra to be unfolded. The number of spectra which may be input is limited by the DIMENSION (20) = RUNS. The spectra, corresponding to card sets 6 and 7, may be stacked together. A background spectrum, if input, must directly follow the unknown spectrum from which it is to be subtracted. Twenty unknown spectra, each followed by a background spectrum, are regarded as twenty spectra from the standpoint of 20 being the maximum number. Each spectrum contains CHANLS (or MNX) channels and background spectra must correspond*}. Each card contains 10 channels of information. Thus, the following is typical of card set (12) as read by subprogram DEC:$

<u>NAME</u>	<u>COLUMN</u>	<u>FORMAT</u>	<u>DESCRIPTION, PURPOSE OR USE</u>
S (1)	1-7	F7.1	Pulse-height analyzer count in channel 1.
S (2)	8-13	F7.1	Pulse-height analyzer count in channel 2.
S (3)	15-20	F7.1	Pulse-height analyzer count in channel 3.
.	.	.	.
S (10)	64-70	F7.1	Pulse-height analyzer count in channel 10.
S (11)	1-7	F7.1	Pulse-height analyzer count in channel 11.
.	.	.	.
S (CHANLS)*	-	F7.1	Pulse-height analyzer count in channel CHANLS.*

(last card in spectrum)

\*For input purposes, if MNX > CHANLS then replace CHANLS above with MNX for unknown and MBX for backgrounds, i.e. CUGEL will read spectra up to 1024 channels in size (per MNX and MBX) but will immediately reduce them to CHANLS = 400, by DEC calling GANE.

### 3.3 CODE OUTPUT

Throughout the discussion in this section, reference to Appendix IV, Sample Code Output Listing, is necessary and understood. Those outputs which are clearly defined by format headings are either not discussed or are mentioned only briefly. Output pages are referred to through the encircled letters A, B, C, etc.

A. The values on this page are output by MAIN, and are as input on card sets (1) to (4), with the exception of EM(=EN/ELIMIT).

B. The values on this page are output by RESFUN, and correspond to those standard source spectral parameters input on card sets (5A) -1 and -2. Indicated channel numbers are those values after shifting with respect to true zero channel has been carried out.

C. The values on this and following similar pages are the standard source spectral counts corrected for input in the complement mode and true zero channel. This output by RESFUN corresponds to card set (5A) -3 input.

D. The results of the Gaussian function regression analysis by STDFT3 for the standard spectra photopeaks are output on these two pages by SPNORM. The output is for the two photopeak energies STDEN (I,1) and STDEN (I,2) and is otherwise self-explanatory.

E. The output on this and the following similar pages, by RESFUN, consists of the Compton continua of the standard source spectra normalized with respect to unit photopeak area and pulse-height. The integral normalized count for the continuum and photofraction are also output.

F. This page presents the response matrix generated by RESFUN and output by MAIN. It corresponds to that input which would be required for card set (5B) -1.

G. This page presents the energies (MeV), pulse-heights (channels) and photofractions corresponding to the generated response matrix, at increment midpoints, as determined by RESFUN and output by MAIN. The photofractions correspond to the solid curve in Figure 4. Standard spectra photopeak standard deviations in channels for unit pulse-height are also output.

H. The output on this page, by MAIN, corresponds to the input specified for card sets (6) and (7), excepting that the units in some cases are modified before output and are as indicated.

I. Optional output by MAIN giving the indices for which unfolding iteration output has been requested by input of card (8).

K. The output on this page by MAIN corresponds to the (first) spectrum to be analyzed and as input on card set (12). Background spectrum subtraction and complement mode correction is carried out before output.

L. Output of spectrum before entry to DISCRT.

M. The output on this page by DISCRT is self-explanatory and refers to the fitting of an monoenergetic spectral component of the unknown spectrum.

N. The output gives the PHA spectrum after stripping of photopeaks and associated continua by SINGLE; gain parameters for subsequent unfolding are also output. The optionally subtracted discrete peak photon number flux at the detector is also given.

O. The output on this page by MAIN corresponds to the unknown spectrum after gain changing and before unfolding analysis.

P. The output on this page by RESMAT is that requested by input of card ⑧. It consists of the gain changed unknown spectrum normalized to unit integral count; output at loop IT, corresponding to that requested (per MN), of the determined photon number spectrum (PHI) and the iterated input spectrum (PP); the iterated spectrum and the iteration convergence loop (IT), the normalizing integral count (SU); the final value of the iteration arresting criterion term ( $TERM = \chi^2$ , Pearson's Chi Square); and the rate of convergence or fitting differences, during unfolding ( $\Delta\chi^2$ ).

Q. The output on this page by DETECT is self-explanatory and consists of the components of the diagonal efficiency matrix,  $\eta$ , defined by Equation (13) of Section 2.2.4.

R. The optional output on this page by MAIN, consists of the efficiency corrected and unfolded spectrum after post-normalization.

S. The optional output on this page, by MAIN, is self-explanatory and consists of  $N_x(E)$  and  $I_x(E)$ , as already discussed in Section 2.2.5.

T. The output on this page, by MAIN, is self-explanatory and consists of SUMNUM, SUMENY, D (Equation 14), AVENGY, etc., in order of, and as already discussed in, Section 2.2.5.

#### 4. SUMMARY AND CONCLUSIONS

A FORTRAN-V, UNIVAC 1108 package code --- CUGEL, has been developed for the rapid analysis of complex gamma photon spectra. The code is readily applicable to the analysis of Ge(Li) semiconductor detector complex-continuous spectra. The response matrix generating portion of the code is suitable for use as a separate entity for problems in spectral analysis such as are frequently encountered in the various fields of gamma spectrometry.

The code employs an iterative unfolding method which has been used successfully by its authors: N. E. Scofield<sup>(5,6)</sup> and R. Gold,<sup>(7)</sup> by the present author<sup>(1-4, 18)</sup> and others.<sup>(8)</sup> While this method is necessarily approximate because of the iterative technique used, it is most suitable where continuous spectra are involved. It is suggested that degree of accuracy be the subject of future work, wherein the iterative method results would be compared with results obtained by other methods. The best value of the matrix size consistent with non-oscillatory good results and computer efficiency would be of interest here. The present contract did not allow for detail studies during the development of code CUGEL.

It is proposed that the response matrix generating portion of the code be made more versatile by studying the use of additional standard sources. A detailed debugging of the code in energy range 1.4 to 3.0 MeV was not possible because of the lack of standard spectra in this range.

It is proposed that standard spectra generated by the Monte Carlo technique be considered for energies in the range 3.0 to 10.0 MeV. NUS has developed such an NaI(Tl) scintillation detector code --- NUGAM-3 --- for NASA/GSFC under contract NAS5-11781. NUGAM-3 considers the crystal cladding and associated photomultiplier. A Ge(Li) code version may be efficiently adapted from NUGAM-3.



It is concluded that the developed code CUGEL is an operable and useful addition to the field or gamma photon spectrometry. It allows the semi-automatic generation of Ge(Li) detector system response function matrices, spectral unfolding process and final analysis of unknown complex-continuous spectra to be carried out in a single computer run; i.e., without human interfacing. It is very suited for modification to on-line applications.

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FIGURES

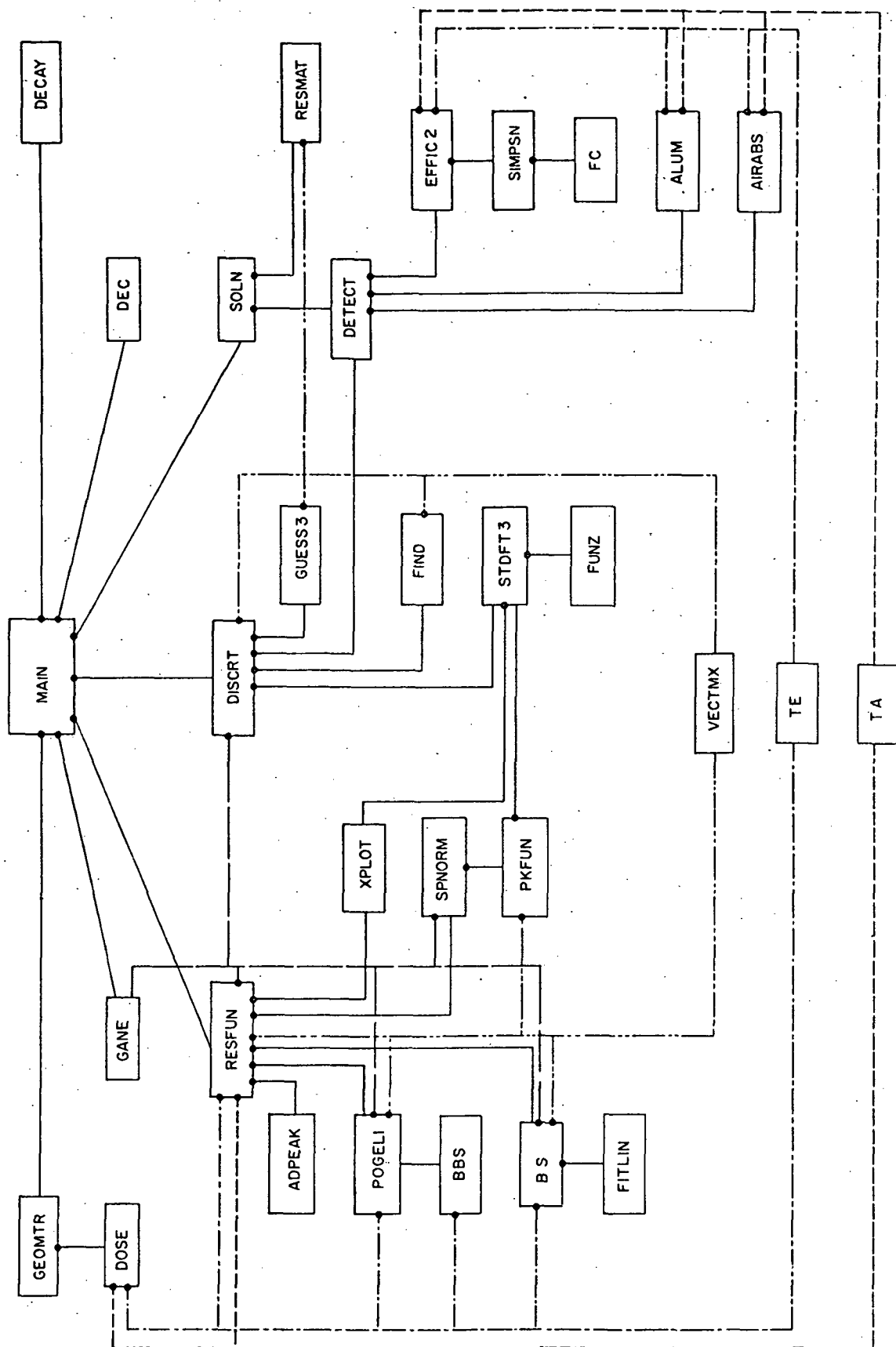
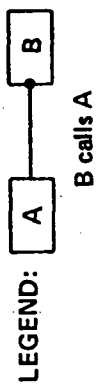


Figure 1  
CODE CUGEL SUBPROGRAM CONNECTIVITY

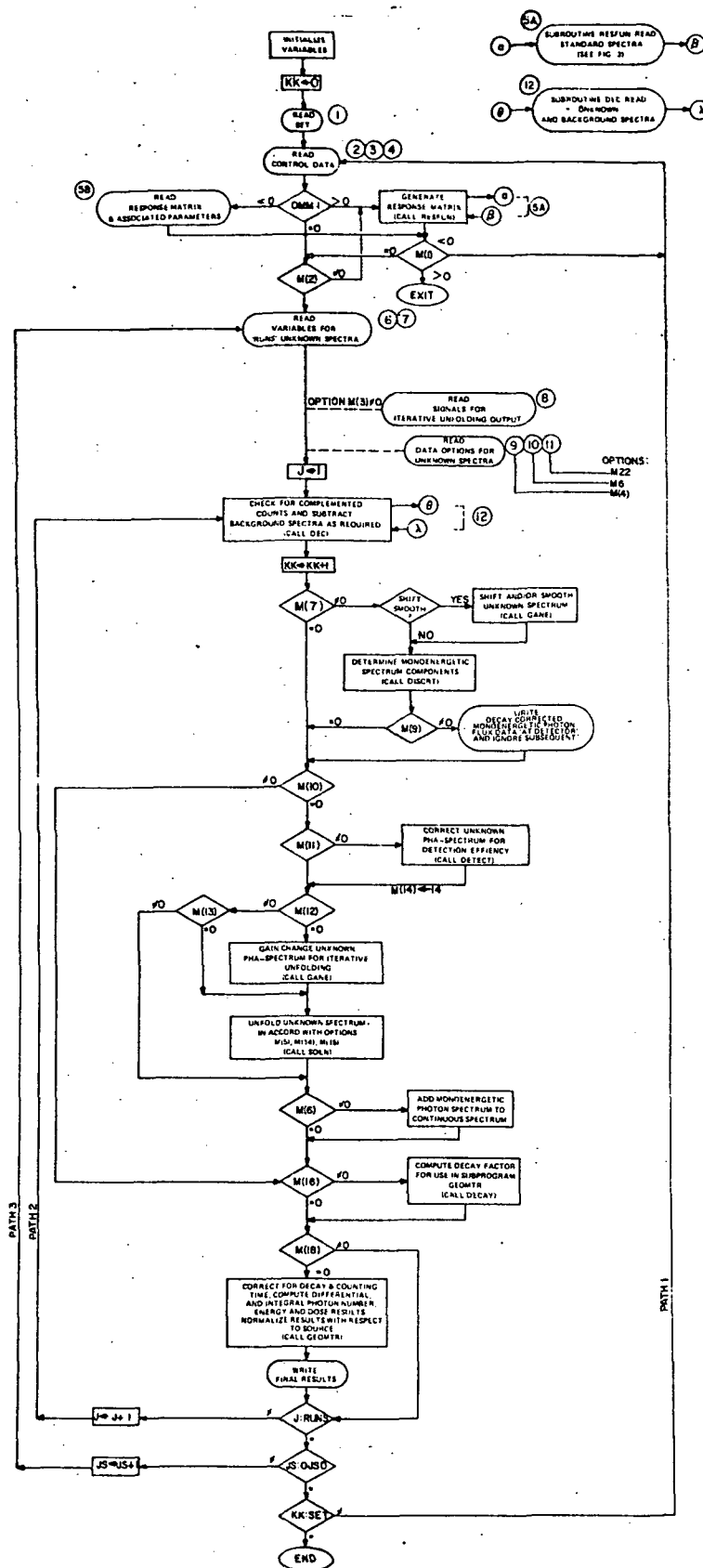


Figure 2  
CODE CUGEL MAIN PROGRAM SIMPLIFIED FLOW DIAGRAM

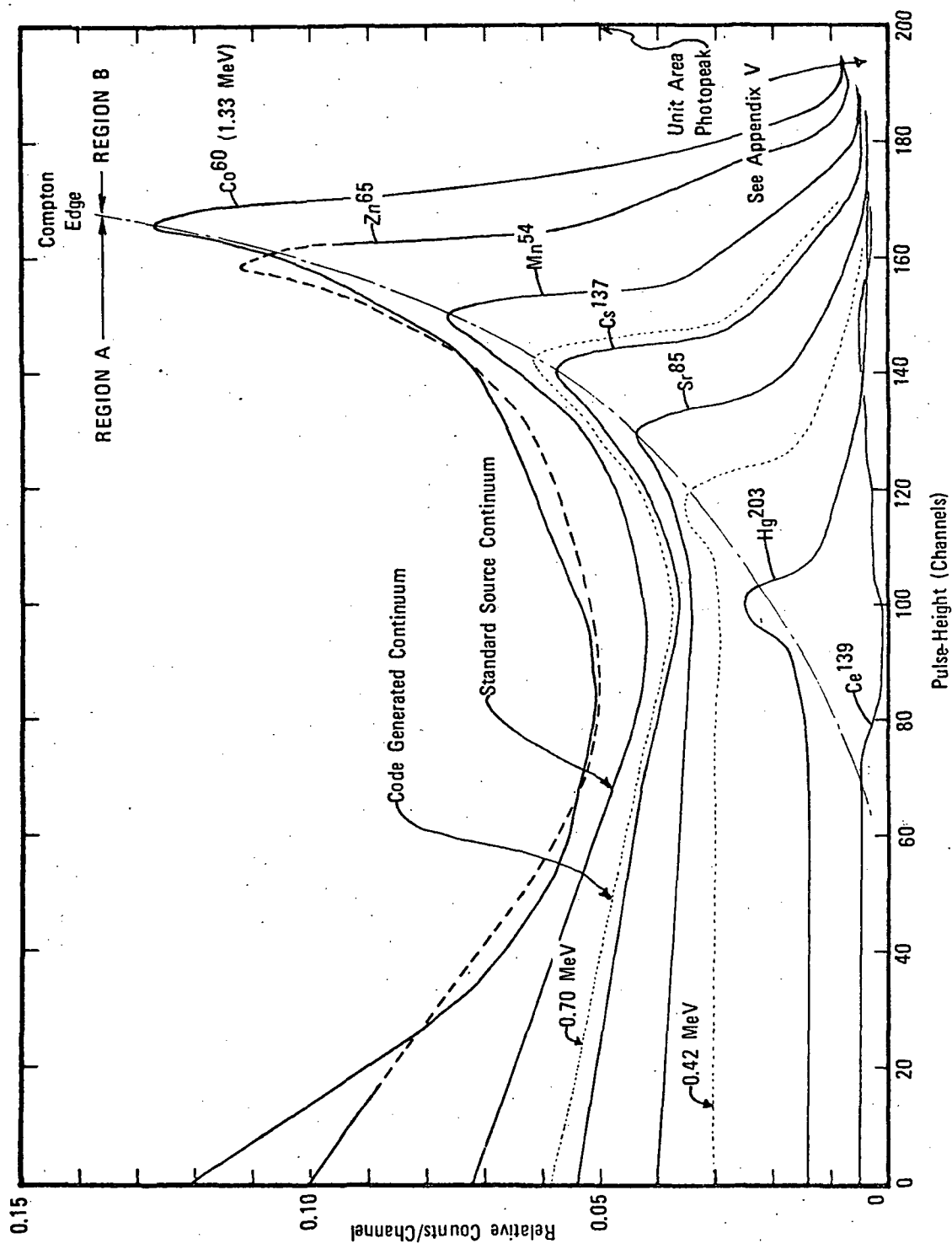


Figure 3  
COMPARISON OF STANDARD SOURCE AND CODE GENERATED COMPTON CONTINUA,  
PULSE-HEIGHT NORMALIZED TO UNIT AREA PHOTOPEAK

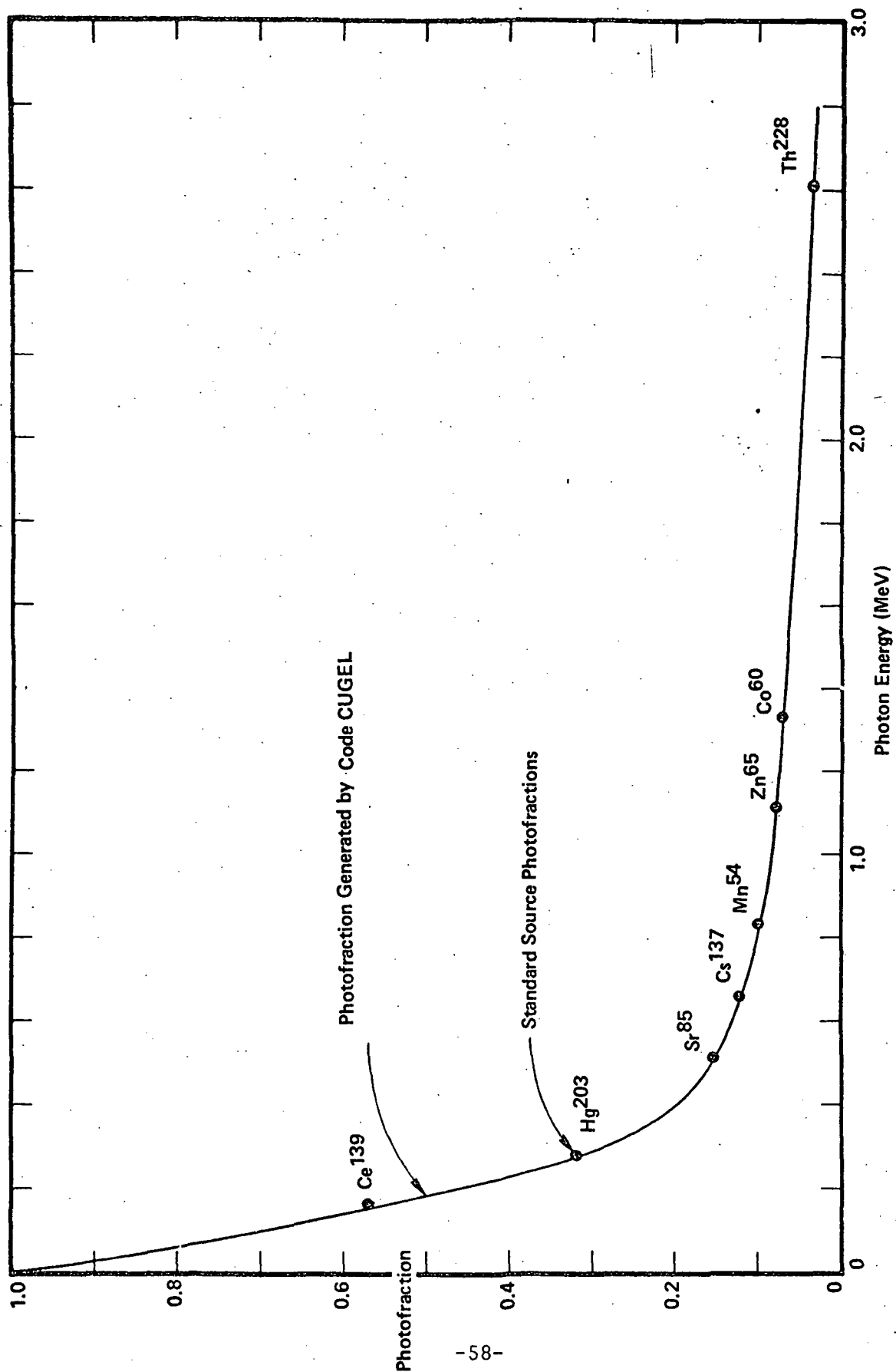


Figure 4

COMPARISON OF STANDARD SOURCE AND CODE GENERATED PHOTOFRACTIONS



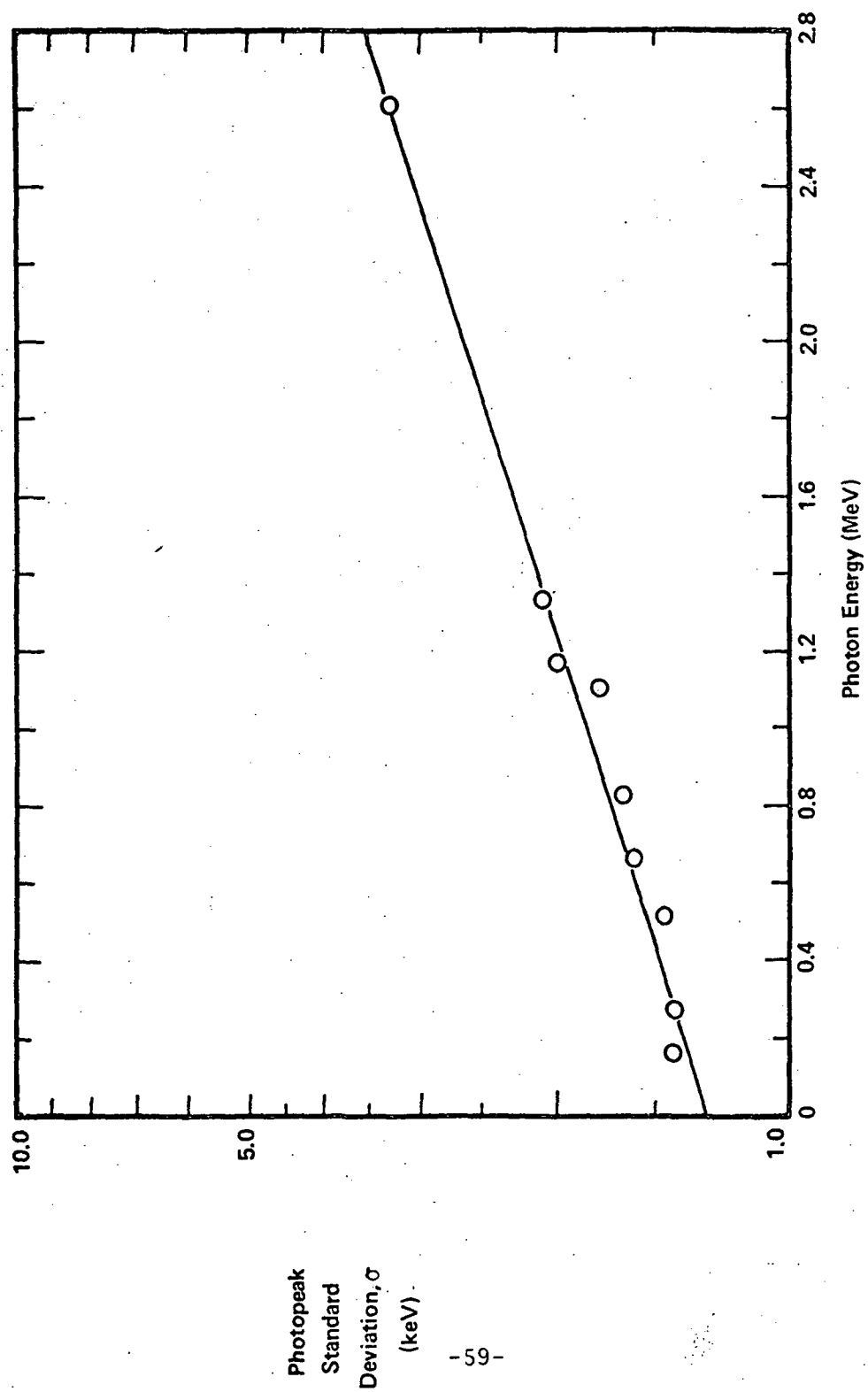


Figure 5  
PHOTOPEAK STANDARD DEVIATION  
FOR FITTED GAUSSIAN AS A FUNCTION OF ENERGY

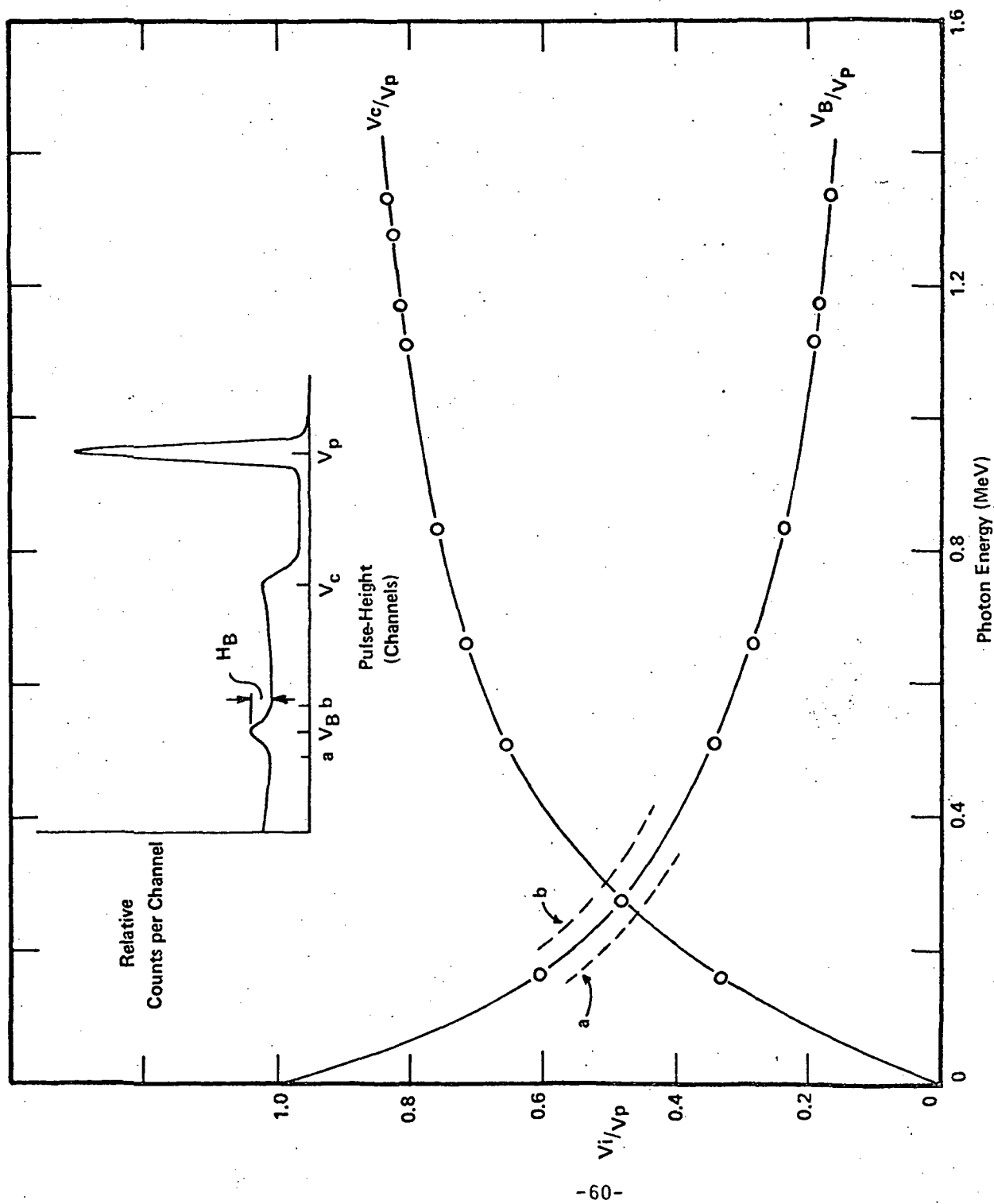


Figure 6  
 VARIATION OF COMPTON EDGE AND  
 BACKSCATTER PEAK PULSE HEIGHTS ( $V_c$  and  $V_b$ )  
 AS A FUNCTION OF PHOTON ENERGY.

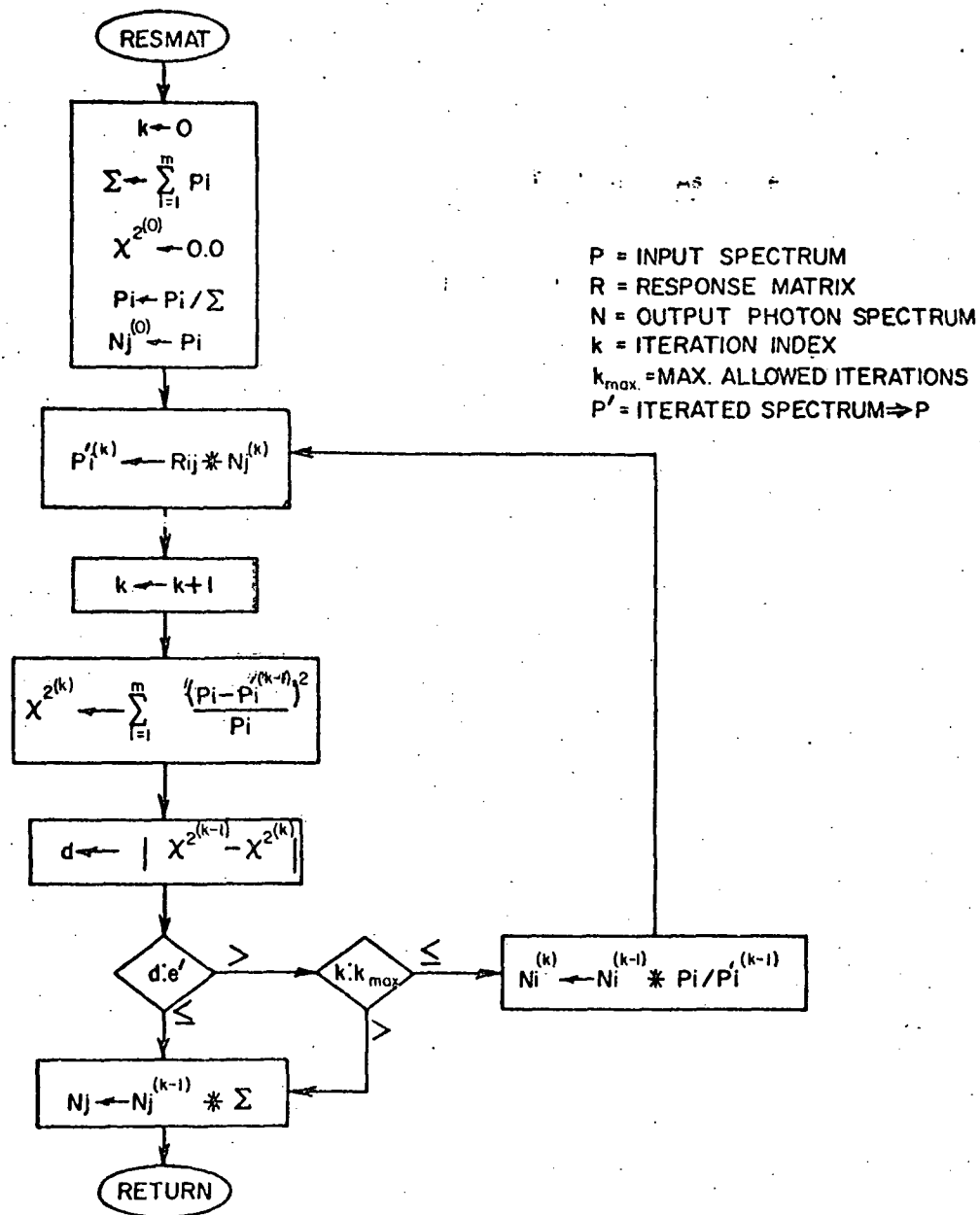


FIGURE 7

FLOW DIAGRAM SHOWING  
THE GENERAL LOGIC OF  
SUBPROGRAM RESMAT

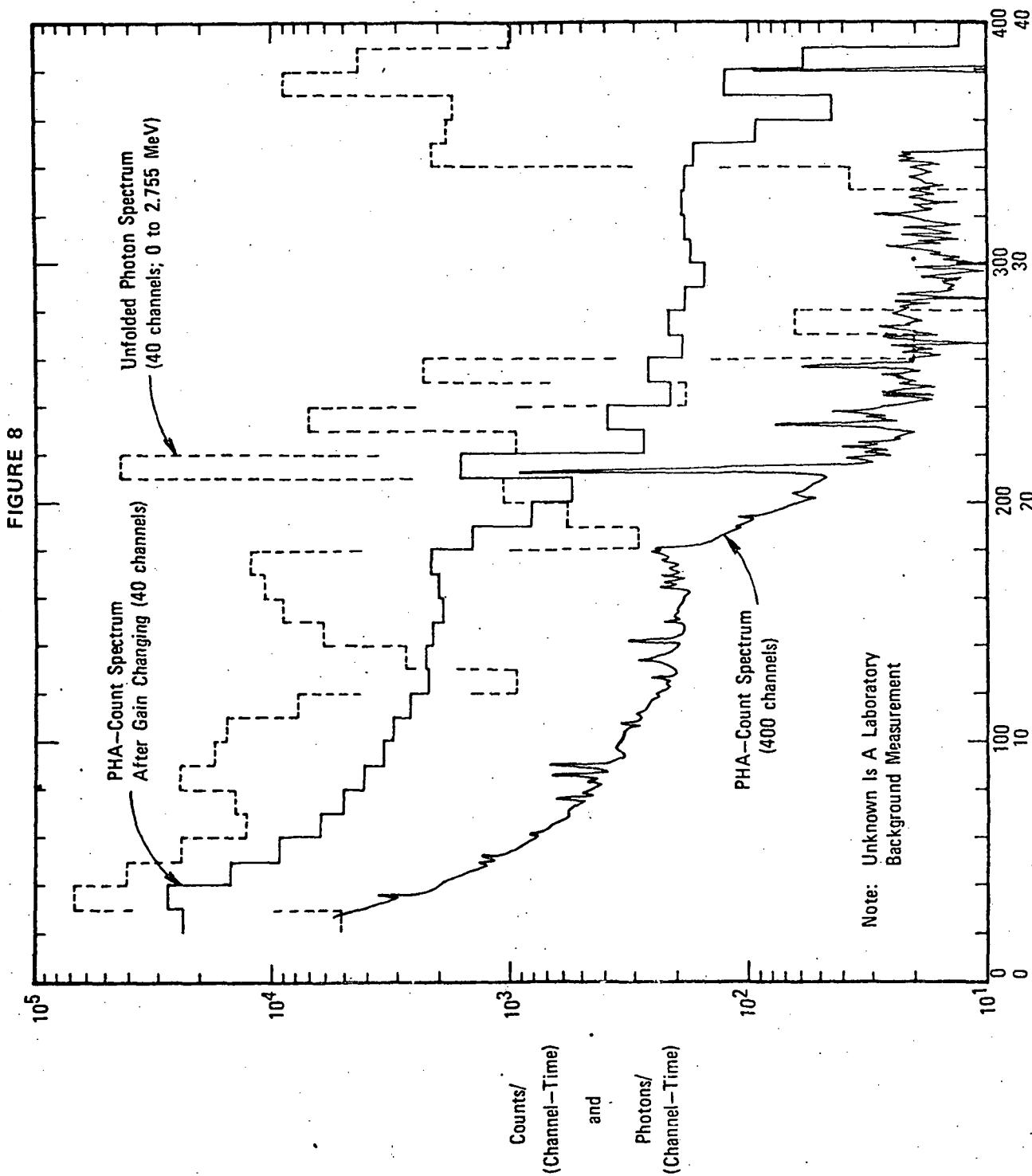


Figure 8  
EXAMPLE UNKNOWN SPECTRUM

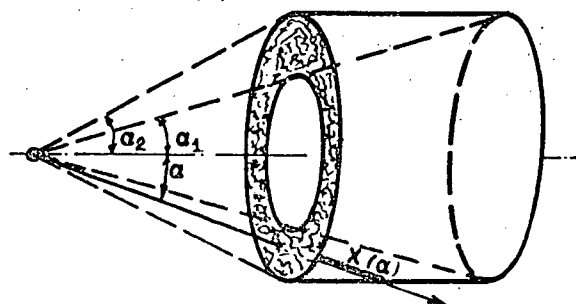
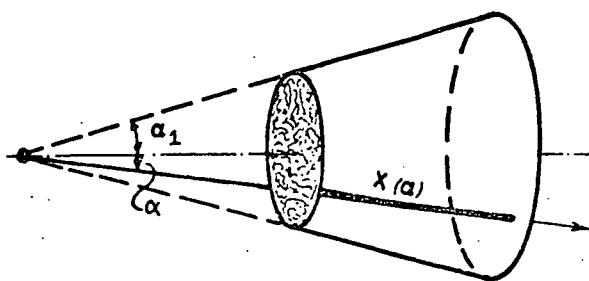
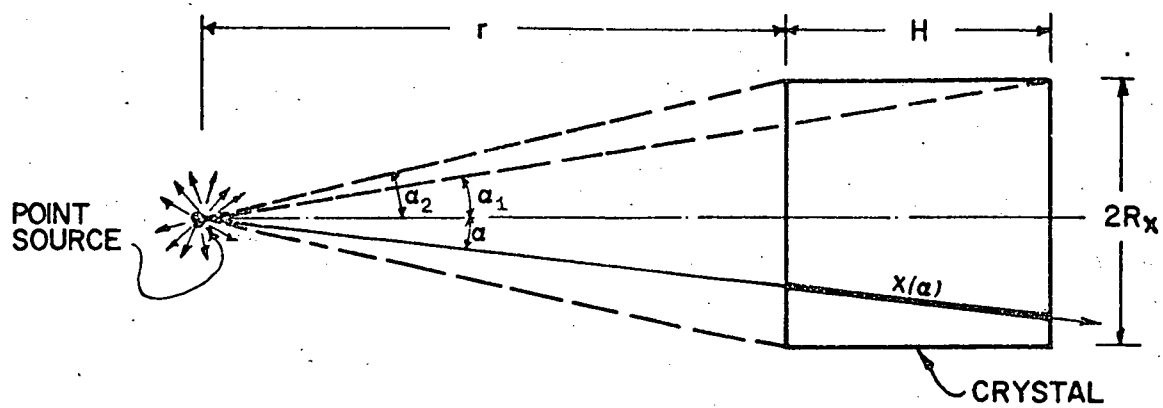


FIG. 9  
GEOMETRY FOR EQUATION (12)

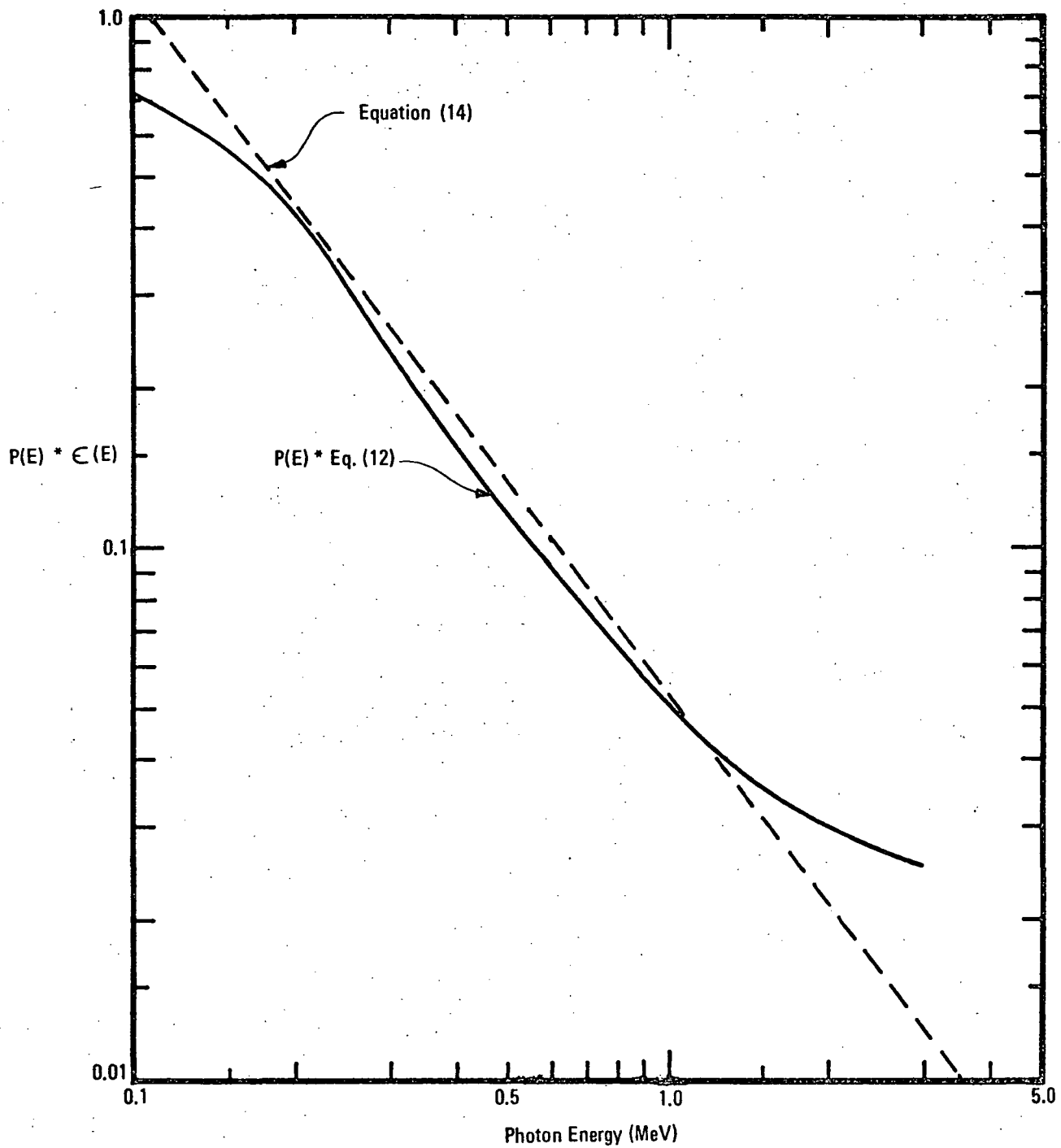


Figure 10  
PHOTOPEAK EFFICIENCY ( $P * \epsilon$ ) AS A FUNCTION OF PHOTON ENERGY

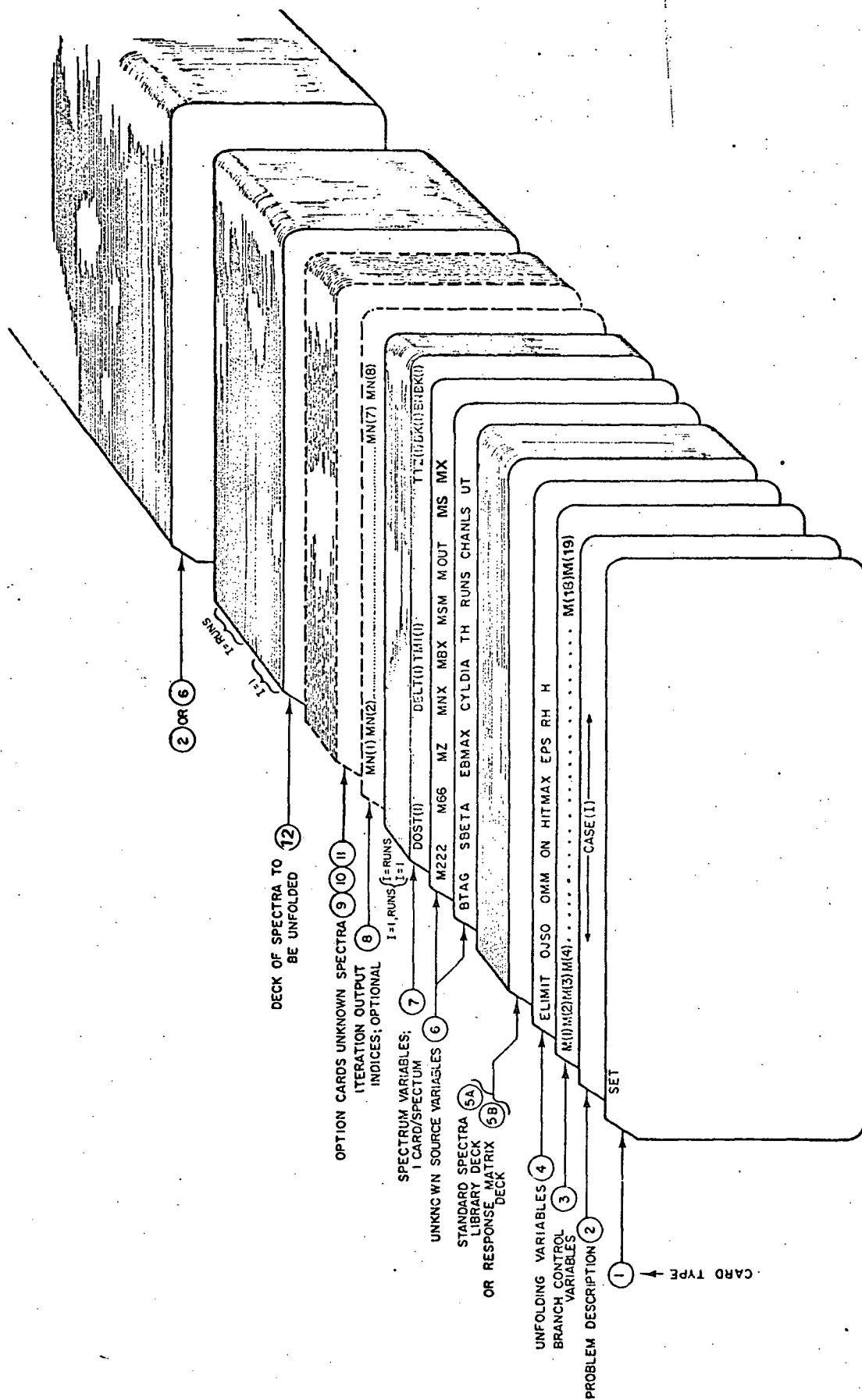


Figure 11  
GENERAL ARRANGEMENT FOR INPUT CARD DATA DECK

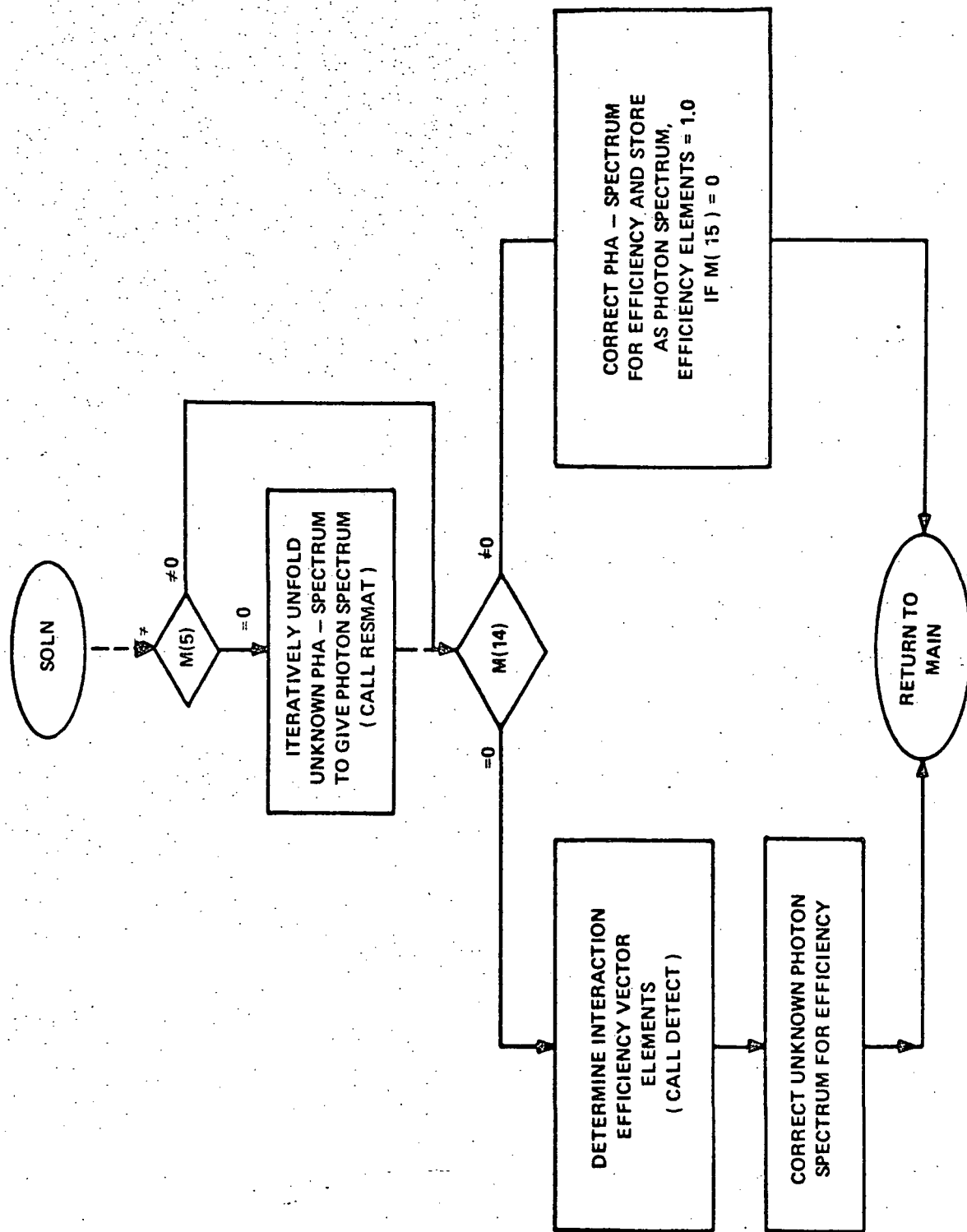


Figure 12  
SUBPROGRAM SOLN SIMPLIFIED FLOW DIAGRAM



APPENDIX I

GLOSSARY OF SUBPROGRAMS

# APPENDIX I

## GLOSSARY OF PROGRAMS FOR CODE CUGEL

(In alphabetical order, except for MAIN)

<u>NUMBER</u>	<u>NAME</u>	<u>FUNCTION or USE</u>	
1	MAIN	Input, output and linking of subprograms.	
2	ADPEAK	Adds photopeaks to interpolated Compton continua.	
3	AIRABS	Computes air attenuation factor.	(F)
4	ALUM	Computes Ge(Li) detector aluminum absorber attenuation factors.	(F)
5	BBS	Interpolates normalized backscatter peaks.	
6	BS	Normalizes and subtracts backscatter peaks.	
7	DEC	Reads pulse-height analyzer spectra; checks for PHA-complemented counts.	
8	DECAY	Computes source decay correction factor.	(F)
9	DETECT	Controls computation of Detector total efficiency.	
10	DISCRT	Determines monoenergetic spectral contribution in unknown spectra.	
11	DØSE	Converts gamma photon flux to exposure dose.	(F)

<u>NUMBER</u>	<u>NAME</u>	<u>FUNCTION or USE</u>	
12	EFFIC2	Computes elements of de- tector interaction efficiency vector.	(F)
13	FC	Ge(Li) interaction efficiency function.	(F)
14	FIND	Determines location of photopeaks in unknown spectra.	
15	FITLIN	Determines continuum base for backscatter and photopeaks.	
16	FUNZ	Photopeak fitting function, par- tial derivatives and Chi-square term for STDFT3.	
17	GANF	Gain changing program; also spectral shifting and smoothing.	
18	GEOMTR	Computes geometry factors, integrates number and energy spectra and calculates nor- malized dose data for final code results.	
19	GUESS3	Provides initial estimates of the photopeak function parameter for non-linear regression analysis in subprogram STDFT3, for double peaks.	
20	PKFUN	Control program for photopeak fitting and subtraction.	
21	POGELI	Interpolates normalized Compton continua by the method of parts.	
22	RESFUN	Control program for response matrix generation.	

<u>NUMBER</u>	<u>NAME</u>	<u>FUNCTION or USE</u>
23	RESMAT	Pulse-height analyzer spectrum unfolding according to the Scofield algorithm.
24	SIMPSN	Simpson's rule integrating program for function FC. (F)
25	SØLN	Control program for unfolding and detector efficiency correction.
26	SPNØRM	Orders and normalizes standard spectra for response matrix interpolation.
27	STDFT3	Non-linear regression analysis of standard spectra photopeaks.
28	TA	Binary table searching program.
29	TE	n-degree Lagrangian interpolation program. (F)
30	VECTMX	Determines the index and value of the maximum valued element in a vector of elements.
31	XPLØT	Plots spectral distributions.

APPENDIX II

FORTRAN CARD DECK LISTING

```

(RUN,A ISWDC, IS040T,841E2I00102,10, 300'
FOR,IS CUGEL
C NUS CORPORATION (J.J.STEYN,U.BORN)
C *****MAIN PROGRAM*****
C *****PROGRAM NUMBER - 1 CUGEL*****
C *****
C CODE *CUGEL*.....CODE TO UNFOLD POLYENERGETIC EXPERIMENTAL DISTRIBUTIONS
C MAIN PROGRAM CONTROLS, INPUTS,OUTPUTS AND CONNECTS SUBPROGRAMS.
C
C DIMENSION CASE(18),M(24),R(40,40),FM(800),PFRAC(40),PV(40),Q(400)
C 1,DIF(100),PHI(400),DOST(20),EU(50), DELT(20), EXX(12), TH(20)
C 2,T72(20),MN(18), ETA(400),ENXTAL(400),BNBK(20),B(400)
C 3,OT(400),EUG(50),PHOT(50),BK(20),N1X(20),N2X(20),NFILL(20),VAL(20)
C COMMON/A/DI,H,MF
C COMMON/SOLRES/EP5,II,ITMAX,MN,DUM3(2),DIF,SIGMA(12)
C COMMON/SING/NJ(50),NSS(50),NFNN(50),GG,NSIN,IN,UIST,MS,MX,PHOT,
C 1 M22,M6,BTAG,BTAGA,CUG,EU,M77,M267,IFIFTY,TEN,IFOUR,SLOP
C COMMON/SPECT/PP(1000)
C COMMON/GAN/NLI
C COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
C COMMON/FUN/DUMFUN(883),NUMFUN(4)
C COMMON/SPN/RDUM(4800),STOEN(12,2),BB(8),PARAV(12,2),PARAS(12,2),
C 1SDUM(48),NSDUM(48),NSTAND
C COMMON/RES/R,N,EM,ELIMIT,NDEGRE,Q,PV,PFRAC,T,K,MRPEAT,ESING,MEM
C COMMON/CNSTNT/T01,T20,T50,T1293,T90,T100,T06
C COMMON/BSI/RVDUM(756)
C COMMON/DOORM/DORM,DOORM
C COMMON/XLIM/NXLIM,IIDUM(17)
C COMMON/B /BBDUM(5)
C COMMON/C/ SUNNUM,SUMENY,DOODET,AVENGY,PHNUBE,ENBENY,PHENBE,
C 1 DOSBEX,DOOSCYL,DBAVOL,DCYVOL ,SBETA ,EBMAX ,CYLDIA
C NRU=20
C IFIFTY=50
C KS=0
C TEN=10.0
C IFOUR=4
C LI=800
C DO 2602 I=1,756
C RVDUM(I)=0.0
C NORN=200
C ORN=NORM
C OORM=ORM-0.5
C NLIMIT=400
C LI=5
C LO=6
C LP=7
C TKLUM=0.9
C T01=0.0001
C T20=20.0
C T50=50.0
C T1293=0.001293
C T90=900000.
C T100=1000000.
C T06=1.0E-06
C MRPEAT=0
C MF=0
C MM=1
C NS=1
C KK=0
C K=0
C NIEGME=2

```

```

11=I.1
SIGMA(I,1)=PARAS(I,1)*OORM/PAVAR(I,1)
207 EX(I,1)=STOEN(I,1)
DO 212 I=NS,N
212 OT(I)=Q(I)
NP=N
121 META=8
MSKIP=1
WRITE (LO,2001)((R(I),J),I=NS,N),J=NS,N)
2001 FORMAT (//34H1SYSTEM RESPONSE FUNCTION MATRIX //(10E11.4))
2009 FORMAT (1H1)
2009 FORMAT (1H1)
2000 FORMAT(49H RESPONSE MATRIX ENERGY INTERVAL MIDPOINTS IN MEV
1 //10F7.4))
WRITE (LO,9876) (PV(I),I=NS,N)
9876 FORMAT (//////37H PULSE-HEIGHT IN CHANNELS (MIDPOINTS) //(10F7.2))
WRITE (LO,30770) (PFRAC(I),I=NS,N)
30770 FORMAT (//37H RESPONSE MATRIX PHOTOFRACTIONS //(1X,10F7.4))
WRITE (LO,2208)(I,EX(I),SIGMA(I),I=1,NSTAN)
2208 FORMAT(//37H INDEX ENERGY STD. DEV //(1X,15.4X,2E14.7))
1 WRITE (LO,2009)
IF(M(1)) 1,16,15
15 CALL EXIT
16 MM=0
2 READ (L1,2000)BTAG,BTAGA,SBETA,EBMAX,CYLDIA,TH,RUNS,CHANLS,UT
1,M22,M6,MZ,MNX,MBS,MSH,M5,MX
200000 FORMAT (2A3 ,4X,5F10.5,2F6.0/815)
NX=CHANLS
NRUN=RUNS
C HALF-LIFE CHECK
40 UT=365.25*1440.
TH=TH*UT
GO TO 50
41 IF (UT-1.)43,42,43
42 TH=TH/60.
GO TO 50
43 IF (UT-60.)44,50,44
44 IF (UT-24.)46,45,46
45 TH=TH*60.
GO TO 50
46 IF (UT-365.)48,47,48
47 TH=TH/1440.
GO TO 50
48 WRITE (LO,49) UT
49 FORMAT (35H HALF-LIFE FACTOR ...ERROR... UT = F10.5, 6H EXIT )
GO TO 15
50 CONTINUE
WRITE (LO,128) BTAG,BTAGA,SBETA,EBMAX,CYLDIA,TH,NRUN,NX,UT ,M22 ,
2 M6 ,MX,MZ,MNX,MBS,MSH,MX
128 FORMAT (1H1, 90H GAMMA SOURCE REFERENCE SOURCE SOURCE
NUMBER OF NUMBER HALF-LIFE /90H SOURCE STRENG
2TH ENERGY DIAMETER HALF-LIFE PHA RUNS OF CHANNELS MULTIPLI
3ER /80H (CURIES) (MEV) (CH.) (MINUTES)
4 THIS SET PER SPECTRUM //3X,2A3 ,3F10.4,E11.4,16.8X,14,
55X,E11.4,//////8X,75H M22 M6 MNX MBX
6 MSH MS MX //2X,8110, ////)
SBETA=SBETA*3.7E+10
DO 5007 I=1,NRUN
5007 I=1,NRUN
DOST(I) =0.0
DELT(I) =0.0
TM1(I) =0.0
BK(I) =0.0
TZ(I) =0.0

```





```

8891 FORMAT (25H AT THE SOURCE CYLINDER //
1 77H PHOTON DOSE / SOURCE EMITTED BETA NUMBER (R/HR)/(BETA/SEC)
2 38H PER. SOURCE VOLUME ((R/HR)/(BETA/SEC))/(CM**3) = .E14.7)
500 CONTINUE
IF (JS-JS0) 61,1111,61
61 JS=JS+1
GO TO 2
1111 IF (KK.LT.NSET) GO TO 1
STOP
END
IFOR IS ADPEAK
SUBROUTINE ADPEAK(FM,NALIM,B1,B2,B3,PH,NF)
C***** PROGRAM NUMBER - 2 CUGEL *****
C
C ADDS PHOTOPEAKS TO INTERPOLATED COMPTON CONTINUA
C
COMMON/L10/LI,LO,LP,NLINIT,NORM,MOUT
DIMENSION FM(800)
SUM=0.0
NS=B1-7.*B2 -1.
NF=B1+7.*B2 +1.
IF (NS.LE.0) NS=1
IF (NF.GT.NALIM) NF= 30
ND=1
NSDFIF=NF-NS+1
52 IF (NSDFIF-50) 51,50,50
51 ND=2*ND
NSDFIF=NSDFIF+NSDFIF
GO TO 52
50 DNN=ND
DN=1.0/(2.0*DNN)
DE=DN*DN
CONS=0.3989423*B3/B2
WRITE (LO,99) B1,B2,B3,DNN,DE,CONS,NS,NF,ND,NSDFIF
99 FORMAT (15H B5,B5, NS /1X,7E15.4/15X,415)
DO 800 I=NS,NF
X=I-1
X=X-DN
WRITE (LO,98) I,X,DN
98 FORMAT (3H I=1,5X,3H X=.E14.4,5X,4HDN= .E14.4)
SAR=0.0
DO 900 II=1,ND
X=X+DE
PON=(X-B1)/B2
PON2=PON*PON
AR=0.5*PON2
IF (AR-20.072*3.3
2 P=CONS*EXP(-AR)*DE
FM(II)=FM(II)+P
SAR=SAR+P
WRITE (LO,97) II,X,PON,PON2,AR,P,FM(II)
97 FORMAT (6H INDEX,15,6E16.5)
3 CONTINUE
900 CONTINUE
SUM=SUM+SAR
SUMP=0.0
DO 555 I=1,NF
555 SUMP=SUMP+FM(II)
DO 555 I=1,NF
5555 FM(II)=FM(II)/SUMP
PH=1.0/SUMP
WRITE (LO,96) NS,NF,NALIM,SUM,PH,B1,B2,B3,SUMP,(I,FM(II),I=NS,NF)
96 FORMAT (7H NS,NF= .315,6E14.7/(110,6E16.4))
RETURN

```

```

END
(FOR,IS AIRABS
FUNCTION AIRABS (E,JUST)
C***** PROGRAM NUMBER - 3 CUGEL *****
C
C COMPUTES AIR INTERACTION FACTOR.
C
DIMENSION X(22),Z(3),Y(3),A(22)
COMMON/CNSINT/101,120,150,11293,190,1100,106
DATA X /,01,02,03,04,05,06,07,08,09,10,2,3,
1,4,5,6,7,8,9,10,15,2,0,3,0/
DATA A /4,97,749,347,243,203,185,174,166,160,
1,155,123,106,0953,0868,080,0750,0706,0668,0635,0517,
2,045,0357,NGO/1/
GO TO (1,2),NGO
1 NGO=2
DO 3 I=1,22
3 A(I)=A(1)*11293
C
2 CALL TA (E,X,22,1,MUX,MUN,Z,Y,A,2,L,0)
C
AERMEW=TE (3,Z,Y,E)
ARG=AERMEW*OIST
IF (ARG-100.0)5,4,4
5 AIRABS=EXP(-ARG)
RETURN
4 AIRABS=EXP(-100.0)
RETURN
END
(FOR,IS ALUM
FUNCTION ALUM (E,TKLUM)
C***** PROGRAM NUMBER - 4 CUGEL *****
C
C COMPUTES ALUMINUM ABSORPTION FACTOR. (F)
C
DIMENSION X(24),R(24),Z(3),Y(3)
DATA X /,01,015,02,03,04,05,06,07,08,09,10,
1,2,3,4,5,6,7,8,9,10,15,2,0,3,0,4,0/
DATA R /71,025,21,17,8,907,2,819,1,369,880,6685,562,
1,5022,462,4330,3232,27806,2486,2268,2097,1958,1842,1735,
2,1655,1349,1165,09534,08365/
C
CALL TA (E,X,24,1,MUX,MUN,Z,Y,R,2,L,0)
C
P=TE (3,Z,Y,E)
ARG=P*TKLUM
IF (ARG-100.0)1,2,2
1 ALUM=EXP(-ARG)
RETURN
2 ALUM=EXP(-100.0)
RETURN
END
(FOR,IS BBS
SUBROUTINE BBS (E,FOUT,JMIN)
C***** PROGRAM NUMBER - 5 CUGEL *****
C
C INTERPOLATES NORMALIZED BACKSCATTER PEAKS
C
COMMON /L10/ L1,L0,LP,NLIMIT,NORM,MOUT
COMMON/SPN/R,STDEN,BDUM(8),PARAV,PARAS,PAREA,DUM(24),NDUM(48),
INSTAND
COMMON/BSI/RV,EBS,VBS,BY
COMMON/XL1M/NXLIM,I5,INZ,INA,ICO,I24,IDUM(12)
DIMENSION R(400,12),Y(3),FM(800),EBS(12),VBS(12),RV(60,12),STDEN(1
12,2),Z(3),BY(12),M1(12),M2(12),NBS(12),M3(12),PARAV(12,2),
2PARAS(12,2),PAREA(12,2),NINT(12)
NDEGRE=2
J5=1
J6=1
J7=1
J8=1
J9=1
J10=1
J11=1
J12=1
J13=1
J14=1
J15=1
J16=1
J17=1
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6 FM(I)=R(I,J)
C WRITE(LO,12)NY,ICO,NSIG,NSI,VBS(J),EBS(J),STDEN(J,JE)
C 12 FORMAT(9H BS TEST ,5I5,3E14.7)
      NM=NORM
      SM1=1.0
      CALL GANE(TAZ,NW,1.0,1.0,SM1,FM)
      NI=VBS(J)-.07*VBS(J)
      N2=VBS(J)+.07*VBS(J)
C WRITE(LO,15) NW,NI,N2,J,NSI,NINT(1),NINT(2)
C CALL VECTHX(FM,N1,N2,JMAX,A)
      NRS(J)=JMAX
      M1(J)=NRS(J)*0.875
      M2(J)=NRS(J)*1.16
      NU1=M1(J)
      NU2=M2(J)
C WRITE(LO,150)NBS(J),M1(J),M2(J),J,N1,N2
      MX=J
C WRITE(LO,7510) (FM(I),I=1,150)
C7510 FORMAT(1X,10E11.4)
      CALL FITLIN(FM,NU1,NU2, MX,JMAX,SLNXX,SLNU1)
      BY(J)=A-SLNXX
C WRITE(LO,157)JMAX,NU1,NU2,MX,M3(J),M9,A,SLNXX,BY(J)
      DO 14 I=NU1,NU2
14 R(I,J)=FM(I)
      IF(STDEN(J,JE)-0.34,65,65.61
61 A1=0.1024*STDEN(J,JE)-0.0137
      A2=SLNU1
      B1=1.0
      B2=NU1
      ES=(A1-A2)/(B1-B2)
      BBB=A1
      DO 710 I=1,NU1
710 R(I,J)=ES+.A1
65 CONTINUE
C WRITE(LO,100) (R(I,J),I=1,NU2)
C WRITE(LO,100) (RV(I,J),I=1,60)
      IF(MX-17503.503,504
504 FF=BY(J)/BY(I)
      DO 505 I=1,60
505 RV(I,J)=RV(I,J)/FF
503 CONTINUE
C WRITE(LO,100) (RV(I,J),I=1,60)
      IF(INSIG-3)64,84,64
84 RETURN
C STANDARD CONTINUA WITH BS-PEAK SUBTR.
C
C 5 NSI=1
      IF(IJ-1)63,63,64
63 IF(STDEN(J,JE).GT.ELOW.AND.STDEN(J,JE).LT.EHIGH)GO TO 62
      GO TO 64
62 EW=STDEN(J,JE)
      BY(I)=0.04112*EW-0.001846
64 IF(J-NY)4,24,24
      J=J+1
C WRITE(LO,156)
      GO TO 25
C
C INTERPOLATE AND SUBTRACT BS-PEAKS OF CONTINUA IN THE ENERGY RANGE
C OF 0.24 TO 0.34 MEV
C
24 IF(NSI)10,11,10
      J=1
41 IF(BY(J))21,8,21
      K=K+1

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NINT(K)=J
21 IF(J-NY)30,31,31
30 J=J+1
      GO TO 41
31 DO 32 JJ=1,K
      J1=NINT(JJ)-1
      J2=NINT(JJ)+1
      J3=NINT(JJ)+2
      J=NINT(JJ)
C WRITE(LO,155)J1,J2,J3,K,J,NINT(1),NINT(2)
      E=STDEN(J,JE)
      Z(1)=STDEN(J1,JE)
      Z(2)=STDEN(J2,JE)
      Z(3)=STDEN(J3,JE)
      Y(1)=BY(J1)
      Y(2)=BY(J2)
      Y(3)=BY(J3)
      BY(J)=TE(3,Z,Y,E)
      FF=BY(J)/BY(1)
C WRITE(LO,5000)JJ,J,NINT(JJ),E,BY(J),FF,Z(1),Z(2),Z(3),Y(1),Y(2),
      Y(3)
C5000 FORMAT (10H BY-CHECK ,3I5,4E14.7/1X,5E14.7)
      DO 70 L=1,60
      Y(1)=RV(L,J1)
      Y(2)=RV(L,J2)
      Y(3)=RV(L,J3)
      RV(L,J)=TE(3,Z,Y,E)
      IF(RV(L,J))71,72,72
71 RV(L,J)=0.0
72 CONTINUE
70 CONTINUE
C WRITE(LO,103) (RV(I,J),I=1,60)
      ERS(J)=STDEN(J,JE)/(1.0*(STDEN(J,JE)/0.511)*2.0)
      VBS(J)=EBS(J)*NORM/STDEN(J,JE)
      NBS(J)=VBS(J)
      KK=NBS(J)*0.875
      L=NBS(J)*1.16
      LA=30-(NBS(J)-KK)
      DO 19 I=KK,L
      KA=LA+1-KK
19 R(I,J)=R(I,J)-RV(KA,J)
C WRITE(LO,2000)JJ,J,KK,L,KA,LA,NBS(J),E,VBS(J),BY(J),FF,Z(1),
      Z(2),Z(3)
C2000 FORMAT(10H,6H BS 6 /1X,7I5/1X,8E12.5)
32 CONTINUE
C 100 FORMAT(10H,6H BS 4 /1X,10F10.8))
C 103 FORMAT(10H,24H INTERPOLATED BS-PEAK ///1X,10F10.8))
C 150 FORMAT(10H,6H BS 2 ,6I5)
C 153 FORMAT(10H,12H POGELI 2 /1X,6F10.6)/(1X,6F10.6))
C 154 FORMAT(10H,12H POGELI 3 /1X,10F10.8))
C 155 FORMAT(10H,11H BS 1 ,7I5//)
C 156 FORMAT(10H,35H ENERGY BETWEEN 0.24 AND 0.34 MEV //)
C 157 FORMAT(10H,10H BS 3 /1X,6I5,4F10.4)
C1001 FORMAT(1X,416//)
C1002 FORMAT(1X,7H P06E //15,3F6.4//)
C1003 FORMAT(1X,3F10.6,3I5)
11 RETURN
      END
IFOR,IS DEC
      SUBROUTINE DEC (NX,S,MX)
      C***** PROGRAM NUMBER - 7 CUGEL *****
C READS PULSE-HEIGHT ANALYZER SPECTRA. CHECKS FOR PHA-COMPLEMENTED COUNTS.
C
      DIMENSION S(400),FM(1000)
      COMMON /L10/ L1,LU,LP,NLIMIT ,NORM,MOUT

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COMMON/CNSTNT/
COMMON/GAN/NLI
IF (MX-NX) I=1,2
2 READ (LI,3000) (FM(I),I=1,MX)
MCX=MX
GO TO 7
1 READ
(LI,3000) (FM(I),I=1,NX)
MCX=NX
3000 FORMAT (10F7.1)
7 DO 4 I=1,MCX
IF (FM(I)-T90) S=5.6
6 FM(I)=FM(I)-T100
5 CONTINUE
4 CONTINUE
IF (MX-NX) I=1,2
20 IF (MX-NX) I=1,2
21 RGAIN=NX
GAIN=MX
MCX=MX
NLI=1000
CALL GANE(0.0,MXX,GAIN,RGAIN,0.0,FM)
NLI=800
11 DO 3 I=1,NX
3 S(I)=FM(I)
RETURN
END
(FOR,IS DECAY
FUNCTION DECAY ( OT,TH,T1, CLAMDA )
C***** PROGRAM NUMBER - 8 CUGEL *****
C
C COMPUTES DECAY CORRECTION FACTOR.
T1=T1*1440.0
IF (OT/TH) - 0.0012,2.1
1 T2=T1 * DT
TE=(1.0/CLAMDA )*ALOG ((EXP(-CLAMDA *T1)-EXP(-CLAMDA *T2))/
1 (CLAMDA *DT))
GO TO 3
2 TE=T1 * DT/2.0
3 DECAY=EXP (CLAMDA *TE)
RETURN
END
IFOR,IS DETECT
SUBROUTINE DETECT(NS,NF,E,H,ETA,DIST,RX,TKLUM,PHOT,M19)
C***** PROGRAM NUMBER - 9 CUGEL *****
C
C COMPUTES DETECTOR TOTAL EFFICIENCY
COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
COMMON/CNSTNT/T01,T20,T50,T1293,T90,T100,T06
DIMENSION E(400),ETA(400) ,PHOT(40)
WRITE (LO,3000)
3000 FORMAT (1H1,50X,18HEFFICIENCY FACTORS /// 8X,5HINDEX,10X,
1 6ENERGY,12X,3HAI,10X,8HABSORBER,
211X,5HTOTAL,
3 22X,5HMEV), 9X,11HATTENUATION,6X,11HATTENUATION,
4 6X,10HEFFICIENCY,7X,10HEFFICIENCY///)
DO 2 I=NS,NF
IF (E(I)-0.01) 5,6,6
5 G=0.0
6 O=E(I)
ABSORB=0.0
ETA(I)=1.0E+20
GO TO 66
6 O=E(I)
IF (M19) 20,20,21

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```

21 ETA(I)=(0.441*O**(-1.32))/PHOT(I)
GO TO 23
20 ETA(I)=EFFIC2(O, DIST,RX,M)
23 G=AIRABS (O,DIST)
ABSORB=ALUM(O,TKLUM)
66 A=ETA(I)*G* ABSORB
WRITE (LO,1000) I,O,G, ABSORB,ETA(I),A
1000 FORMAT (1H ,8X,I3, 6E17.5)
2 ETA(I)=A
RETURN
END
(FOR,IS DISCHT
SUBROUTINE DISCHT (FM,ETA,NP,RX,TKLUM,M19)
C***** PROGRAM NUMBER - 10 CUGEL *****
C
C DETERMINES MONOENERGETIC SPECTRAL CONTRIBUTION.
DIMENSION FM(800),SLINE(400),EUG(50),EU(50),
1(40),PFRAC(40),O(400),PHOT(50), NSS(50),NFNN(50),ETA(400)
2 *EUG(50),EU(50),NAS(50),NAF(50),NAJ(50),88(81,NSM(50)
3 ,TITLE(2),NPARA(8) ,FA(80),PH(1)
C
C FM-IN IS A BREMS- LINE SPECTRUM. FM-OUT IS A BREMS ONLY, AND PHOT
C CONTAINS THE LINE DATA TO BE ADDED TO PHI IN *MAIN*.
COMMON/A/DI,H,MF
COMMON/RES/RM,N,EM,ELIMIT, NDEGRE,Q,PV,PFRAC,K,MREPEAT,ENY,
1 MEM
COMMON/LIO/LI,LO,LP,NLIMIT ,NORM,MOUT
COMMON/SING/NJ(50),NSS,NFNN,GG,NSIN,IN,DIST,MS,MX,PHOT,M22,M6,
1 BTAG,BTAGA,EUG,EU,M77,M267 ,IFIFTY,TEN,IFOUR,SLOP
COMMON/SPCT/PP(1000)
COMMON/CNSTNT/ T01,T20,T50, T1293,T90,T100, T06
COMMON/FUN/DUMFUN(483),NUMFUN(4)
COMMON/SPN/RDUM(4800),STDEN(12+2),8(8),PARAV(12+2),PARAS(12+2),
1SDUM(48),NSDUM(48),NSTAND
COMMON/XLIM/NXLIM,IIDUM(17)
COMMON/OOORM/ORM,OOHM
COMMON/GAN/NLI
C
C WRITE (LO,1111) (FM(I),I=1,400)
C1111 FORMAT(10H SINGLE 00 /(1X10E12+6))
C
C WRITE (LO,1113)M22,M6, IN,M77, (J,NSS(J),NFNN(J),NJ(J),EU(J),
C 1 EUG(J),J=1,20)
C1113 FORMAT(10H M22, M6= ,4110/(1X,4110.2E14,7))
NLI=800
NONE=1
NX=1
NOX=NX
HH=H
MB=8*NOXM
KM=0
IF (M6+8001-8000,8001
8001 DO 1501 J=1,M6
EUG(J)=EU(J)/SLOP
SIG=(1.2*0.00128*EXP(0.395*EU(J)))*EUG(J)/EU(J)
NS=EUG(J)-6.0*SIG-0.5
NFN=EUG(J)*6.0*SIG-0.5
CALL VECTMX(FM,NS,NFN,IBIG,BIG)
EUG(J)=IBIG
NNS(J)=EUG(J)/6.0*SIG-0.5
NFNN(J)=EUG(J)*6.0*SIG-0.5
WRITE (LO,9555)NSS(J),NFNN(J),SIG,EUG(J),EU(J)
C9555 FORMAT(10H SINGLE 1 /1X,2110.3E14,7)
NJ(J)=1
1501 CONTINUE
KM=1

```

8000 IF (M22)8005,8007,8008  
C CHECK-OUT ESTIMATED FITTING LIMITS.  
8005 J=M77

KM=KM+1

502 NS=NSS(J)

NOJ=0

IF (NJ(J)-2)504,503,504

503 NFN=NFN(J+1)

NOJ=2

GO TO 506

504 NFN=NFN(J)

506 CONTINUE

WRITE(LO,1112)NS,NFN

C1112 FORMAT(9H NS, NFN / (2I8))

CALL VECTAK(FM,NS,NFN,IBIG,BIG)

EUG(J)=IBIG

507 IF (EUG(J))5000,5000,5002

5000 EUG(J)=EUG(J)\*SLOP

5002 CONTINUE

IF (NOJ)509,8006,509

509 NOJ=0

JP1=J+1

562 EUG(JP1)=IBIG\*NSS(J+1)

NEUG=EUG(JP1)

IF (FM(NEUG)-FM(NS)) 560,560,561

560 NSS(JP1)=NSS(JP1)

GO TO 562

561 J=JP1

GO TO 507

8006 IF (J-IN)501,500,500

501 J=J+1

GO TO 502

500 CONTINUE

8007 IF (MS-MX)7008,7008,8070

8070 CALL FIND(FM,MS,MX,IN,IFOUR,IEN,IFIFTY,M670,M267,EUG,NSS,NFN,

1 SLOP,EU,NJ

KM=KM+1

7008 IF (KM-1)56,56,4441

4441 DO 5049 J=1,IN

EU(J)=EUG(J)

NAS(J)=NSS(J)

NAF(J)=NFN(J)

NAJ(J)=NJ(J)

EUGN(J)=EUG(J)

DO 5053 JK=1,IN

SHALL=10000.

DO 5050 J=1,IN

IF (EUG(J)-SMALL)5051,5052,5052

5051 SMALL=J

SHALL=EUG(J)

5052 CONTINUE

5050 CONTINUE

NSM(JK)=NSMALL

EUG(NSMALL)=10000.

5053 CONTINUE

DO 5057 J=1,IN

NORDER=NSM(J)

EUG(J)=EUGN(NORDER)

EU(J)=EU(NORDER)

NSS(J)=NAS(NORDER)

NFN(J)=NAF(NORDER)

NJ(J)=NAJ(NORDER)

IEN=IN-1

DO 769 J=1,IEN

JNS=J+1

IF (NFN(J)-NSS(JNS))762,762,763

763 MEAN=(NFN(J)-NSS(JNS))/2  
NFN(J)=NFN(J)-MEAN  
NSS(JNS)=NFN(J)+1  
762 CONTINUE  
IF (NSS(J)-1)64,64,65  
64 NSS(J)=2  
65 IF (NFN(J)-NSM)66,67,67  
67 NSS(J)=NSM+1  
66 CONTINUE  
769 CONTINUE  
IF (NFN(IN)-NSIN)56,57,57  
57 NSS(J)=NSIN  
56 CONTINUE  
NSM=NSIN+1  
DO 766 I=NSM,NLI  
766 FM(I)=0.  
C WHITE (LO,1115) (FM(J),J=1,400)  
C WRITE(LO,1113)M22,M6, IN,M77, (J,NSS(J),NFN(J),NJ(J),EU(J),  
C 1 EUG(J),J=1,IN)  
C

TITLE(1)=BTAG  
TITLE(2)=BTAGA  
J=1

8015 NBS=0

IF (NJ(J)-2)8011,8010,8011

8010 NS=NSS(J)

NFN=NFN(J+1)

577 V1=EUG(J)

V2=EUG(J+1)

IF (V1-V2) 575,575,576

576 EUG(J)=V2

EUG(J+1)=V1

GO TO 577

575 GO TO 8016

8011 NS=NSS(J)

NFN=NFN(J)

VENY=EUG(J)

VENY=EUG(J)

IF (NFN-NS)-6)515,515,8016

515 BB(3)=0.0

EE=(FM(NFN)-FM(NS))/(NFN-NS)

BBB=0.0

DO 517 I=NS,NFN

SLINE(I)=FM(I)-(FM(NS)+EE\*(I-NS))

BBB=BBB+SLINE(I)\*(I-NS-0.5)

FM(I)=FM(I)-SLINE(I)

517 BB(3)=BB(3)+SLINE(I)

BBB=BBB/BB(3)

BB(1)=NS+BBB

BB(1)=BB(1)

EU(J)=BB(1)\*SLOP

ENY=EUG(J)

BB(3)=BB(3)

BB(2)=0.

GO TO 8020

8016 DO 760 I=1,NLIMIT

760 SLINE(I)=0.0

DO 761 I=NS,NFN

SLINE(I)=FM(I)

C WHITE(LO,1115) (SLINE(I),I=1,400)

C1115 FORMAT (7H SLINE / (1X,10E11.4))

IF (NJ(J)-2)8013,8012,8013

C FIT DOUBLE PEAK AND SUBTRACT.

8012 BB(1)=V1

BB(3)=V2

BB(2)=(1.2\*0.00128\*EXP(0.395\*EU(J))\*V1)/EU(J)

```

BB(4)=BB(2)
CALL GUESS3(NS,NFN,SLINE,BB,V1,V2)
NPARA(1)=1
NPARA(2)=3
NPARA(3)=4
NPARA(4)=6
CALL STOPT3(SLINE,BB,NFN,NS,4,2,NPARA,NIS,FA,TITLE,1)
CALL STOPT3(SLINE,BB,NFN,NS,4,2,NPARA,NIS,FA,TITLE,0)
NIS=NS
DO 1351 I=1,NS,NFN
  IF(I=NS) 1
  FM(1)=FA(1)
  IF(BB(1)-BB(4)) 516,518,518
516 IF(EU(J)-EU(J,1)) 519,519,518
518 AT=EU(J,1)
  EU(J)=EU(J,1)
  JPI=J+1
  EU(JPI)=AT
519 CONTINUE
  B(1)=BB(1)
  B(2)=BB(2)
  B(3)=BB(3)
  B(4)=BB(4)
  B(5)=BB(5)
  EU(J)=BB(1)*ELIMIT/GG
  VENV=BB(1)
  ENY=EU(J)
  NBS=1
  GO TO 8020
8013 BB(1)=EU(J)
  BR(2)=(1.2*0.00128*EXP(0.395*EU(J)))*EUG(J)/EU(J)
  NS=NS(J)
  NFN=NFN(J)
  CALL VECTMX(SLINE,NS,NFN,JMAX,YMAX)
  BB(3)=BB(2)*2.35*(YMAX-((SLINE(NFN)*SLINE(NS))/2.0))
  XNF=NFN-NS+1
  BB(4)=(SLINE(NS)-SLINE(NFN))/(-XNF)
  BB(5)=SLINE(NS)
  NPARA(1)=1
  NPARA(2)=2
  NPARA(3)=3
  NIS=NS
  ENY=BB(1)*SLOP
  CALL STOPT3(SLINE,BB,NFN,NS,3,1,NPARA,NIS,FA,TITLE,1)
  CALL STOPT3(SLINE,BB,NFN,NS,3,1,NPARA,NIS,FA,TITLE,0)
  DO 1350 I=NS,NFN
    IF(I=NS) 1
  1350 FM(1)=FA(1)
  8020 DO 99 I=1,NLIMIT
    PP(1)=0.0
    MRPE=MRPEAT
    MENY=MEM
    NNP=N
    N=NP
  CALL RESFUN
  N=NP
  MRPEAT=MRPE
  MENY=MEMY
  DO 850 I=1,NLIMIT
    IF(PP(1)) 851,851,852

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851 INDEX=1
  GO TO 853
852 CONTINUE
850 CONTINUE
853 DO 854 I=INDEX,NLIMIT
  854 PP(1)=0.0
  SUM=0.0
  DO 999 I=1,NORM
    SUM=SUM+PP(1)
  PHOT(J)=1.0/(1.0+SUM)
  NX=NORM
  GAINB1=B(1)
  PHO=PHOT(J)
  C 1 WRITE (LO,19888) K,NS,NFN,MRPEAT,MENY,NORM,HOUT,NSIN,NSN,
  C 1 NLI,EM,ELIMIT,ENV,GAINB1,PHO,VENTY,EE,B(2)
  C9888 FORMAT (6H TEST ,1215/1X,8E13.6)
  C 1 WRITE (LO,19777) NP,EM,BB(1),BB(3),PHOT(J),FM(1),I=NS,NFN)
  C9777 FORMAT (10H SINGLE 3 /1X,110.4E14.7/(1X,5E14.7))
  CALL GANE(0.0,NX,00KM, GAINB1,0.0,PP)
  C
  IF(NX-NLIMIT) 1800,1801,1801
  1801 NX=NLIMIT-1
  1800 DO 1100 I=1,NX
    FM(1)=FM(1)-PP(1)*B(3)
    IF(FM(1)) 1873,1874,1874
  1873 FM(1)=0.0
  1874 CONTINUE
  1100 CONTINUE
  C 1 WRITE(LO,800) NX,GAINB1,(FM(1),I=1,NLIMIT),PP(1),I=1,NLIMIT)
  C 800 FORMAT (10H SINGLE 3A ,110.4E14.7/(1X,5E14.7))
  PHOT(J)=B(3)/PHOT(J)
  ETAT=ETA(J)
  J1=J
  SLINE(J)=ENV
  PH(1)=PHO
  C
  CALL DETECT(J1,J1,SLINE,HH,ETA,DIST,RX,TKLUM,PH,M19)
  C
  PHOT(J)=PHOT(J)/ETA(J)
  ETAT(J)=ETAT
  WRITE(LO,555) PHOT(J),PHO
  555 FORMAT(1H0//69X,25HPHOTON NUMBER
  1 69X, 25HPHOTOFRACTION
  =E20.7//
  =E20.7//)
  WRITE(LO,1500)
  1500 FORMAT (1H0//43X,31HDISCRETE PHOTOPEAK FITTING DATA ///
  1 6X,8HLOCATION,15X,6HENERGY,16X,12HPULSE-HEIGHT,10X, 18HSTANDARD
  2 DEVIATION,14X,4HAREA/ 19H CHANNEL TO CHANNEL,10X,5H(MEV),18X,
  3 10H(CHANNELS),15X,10H(CHANNELS),14X,13H(COUNTS/TIME)//)
  WRITE(LO,1600) NS,NFN,ENV,B(1),B(2),B(3)
  1600 FORMAT (1H ,2X,13,8X,13,E22.7,3E25.7)
  100 IF(J-IN) 9020,8030,9020
  9020 J=J+1
  IF(NBS) 8040,8015,8040
  8040 NBS=0
  DO 8041 I=1,NLIMIT
  8041 SLINE(I)=0.0
  DO 8042 I=NS,NFN
  8042 SLINE(I)=FM(1)
  EUG(J)=BB(4)
  VENV=EUG(J)
  B(3)=BB(6)
  B(2)=BB(5)
  B(1)=BB(4)
  IF(EU(J)) 532,532,534
  534 ENY=EU(J)
  GO TO 533

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532 ENY=BX(4)*SLOP
533 GO TO 8020
8030 NX=NOX
840 RETURN
END
IFOR=IS DOSE
FUNCTION DOSE (E)
C***** PROGRAM NUMBER - 11 CUGEL *****
C
C COMPUTES GAMMA PHOTON DOSE.
C
C DIMENSION X(20),R(20),Z(3),Y(3)
C
C DATA X /0.1,0.15,0.02,0.03,0.04,0.05,0.06,0.08,0.1,0.15,0.2,0.3
C 1 0.4,0.5,0.6,0.8,1.1,1.5,2.3,4.5,7.23,1.25,32.5,50.292,1.14456,0.06216,0.03767,0.02864
C DATA R /4.5723,1.25,32.5,50.292,1.14456,0.06216,0.03767,0.02864
C 1 0.02364,0.02321,0.02511,0.02681,0.02874,0.02954,0.02966,0.02959,0.02884,
C 2 0.2794,0.02556,0.02355,0.02071/
C
C CALL TAIE,X,20,1,MOX,MUN,Z,Y,R,2,L,0)
C
C DOSE=TE ( 3,Z,Y,E)*E
C RETURN
C
IFOR=IS EFFIC2
FUNCTION EFFIC2(E,DAST,ROX,MH)
C***** PROGRAM NUMBER - 12 CUGEL *****
C
C COMPUTES ELEMENTS OF DETECTION EFFICIENCY VECTOR.
C
C COMMON/CNSTNT/101,120,150,11293,190,1100,106
C COMMON /L10/ L1,LO,LP,NLIMIT,NORM,MOUT
C COMMON /B/ KL,UEGAM,RX,DIST,H
C DIMENSION X(29),R(29),Z(3),Y(3)
C DIST=DAST
C
C H=HH
C RX=ROX
C ARG=RX/(DIST*H)
C EPS=T06
C WRITE(LO,100)DIST,H,RX,ARG
C 100 FORMAT(1X,4E14.7)
C
C DATA X /1.125,0.150,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1.0,1.25,1.5,2.0,2.5,3.0,3.5,
C 24.0/
C DATA R /1126,4,504,0.3,226,85,72,34,31,40,16,59,10,127,
C 17,00,4,725,3,52,2,7615,1,800,1,2444,0,8301,0,5742,4804,42694,
C 2,3893,3600,3363,3185,30183,2685,24634,21642,1992,18726,
C 3,1795,17394/
C WRITE(LO,110)(1,X(1),R(1),1=7,29)
C 110 FORMAT(1X,15,2E14.7)
C
C CALL TA (E,X,29,1,MOX,MUN,Z,Y,R,2,L,0)
C
C UEGAM=TE (3,Z,Y,E)
C WRITE(LO,120) MOX,MUN,L,UEGAM,E
C 120 FORMAT (1X,315,2E14.7)
C IF(ARG-0.0124)6,6,5
C 5 A=0.0
C B=ATAN(ARG)
C KL=0
C CASE=SIMPSN(A,B,EPS)
C A=B
C B=ATAN(RX/DIST)
C KL=1

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```

9 IF (I8IG-NOP) 35,36,35
35 NOP=181G
J=J+1
IF (J-IFIFTY) 37,37,18
37 P(J)=181G
EU(J)=P(J)*SLOP
NS(J)=N1
NF(J)=N2
NJ(J)=3
GO TO 5
36 NF(J)=N2
5 CONTINUE
12 CONTINUE
17 I=1+1
IF (I-MX) 17,18,18
GO TO 501
18 M267=J
IF (M267-IN) 118,118,119
119 IN=M267
118 CONTINUE
C
C 1 WRITE (LO,200) M267,IN,MS,MX,M678,IFOUR,IFIFTY,TEN,SLOP,
C 1 (J,P(J),EV(J),NS(J),NF(J),NJ(J),J=1,IN)
C 200 FORMAT ( 6H FIND ,715,2E14.7/(1X,15,5X,2E14.7,3110))
RETURN
END
(FOR,IS FITLIN
SUBROUTINE FITLIN(FM,M1,M2, MX,NYX,SLNYX,SLNU1)
C***** PROGRAM NUMBER - 15 CUGEL *****
C
C STRAIGHT-LINE BASE FITTING
COMMON/LIO/LI,LO,LP,NL,INIT,NORM,MOUT
COMMON/BSI/RBS,VOUN(36)
DIMENS:CN FM(800),RBS(60,12)
M3=M2-M1
N1=M1-5
N2=M2+5
SUMX=0.0
SUMX2=0.0
SUMY=0.0
SUMXY=0.0
DO 1 I=N1,M1
SUMX=SUMX+1
SUMY=SUMY+FM(I)
SUMX2=SUMX2+1+1
SUMXY=SUMXY+1+FM(I)
DO 2 I=M2,N2
SUMX=SUMX+1
SUMX2=SUMX2+1+1
SUMY=SUMY+FM(I)
A=SUMX*SUMX-SUMY*SUMX2
B=SUMX*2-12.0*SUMX2
BE=A/B
EM=(SUMY-BE*12.0)/SUMX
SLNYX=EM*NYX+BE
SLNU1=EM*M1+BE
C
C 101 FORMAT(1H0,13H FITLIN 2 /1X,6E14.7)
IF (M3-1) 110,11,10
C
C LOAD ALIGNED (IN CH.30) BS PEAK IN RBS
10 ND=NYX-30
DO 7 I=M1,M2
J=I-ND
RBS(J,MX)=FM(I)-(EM*I+BE)
FM(I)=EM*I+BE

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```

IF (RBS(J,MX)) 5,6,6
5 RBS(J,MX)=0.0
6 CONTINUE
7 CONTINUE
11 RETURN
END
(FOR,IS FUNZ
SUBROUTINE FUNZ(NPK,B,FA)
C***** PROGRAM NUMBER - 16 CUGEL *****
C
C COMPUTES NP GAUSSIANS
COMMON/FUN/A(80,8),Y(80),FC(80),FU(80),FIT,ON,DNN,NS,NF,ND,MP
COMMON/LIO/LI,LO,LP,NL,INIT,NORM,MOUT
DIMENSION B(8),FA(80)
FIT=0.0
DO 50 I=1,80
FU(I)=0.0
FC(I)=0.0
DO 50 J=1,8
A(I,J)=0.0
50 PHOTOPEAK BASE
DE=DN*DN
NPS=NPK*3+1
NP1=NPS+1
WRITE(LO,99)NPK,NS,NF,ND,MP,DNN,(B(I),I=1,5)
FORMAT(6H FUN 1,515,7E12.5)
DO 403 I=NS,NF
X=I
X=X-0.5
FU(I)=B(NPS)*X + B(NP1)
FA(I)=FU(I)
A(I,NPS)=X
403 A(I,NP1)=1.0
NP PHOTOPEAKS (GAUSSIANS)
DO 700 K=1,NPK
NMULT=3*(K-1)
NP1=NMULT+1
NP2=NMULT+2
NP3=NMULT+3
CONS=0.3989423*B(NP3)/B(NP2)
DO 800 I=NS,NF
X=I-1
X=X-DN
DO 900 II=1,ND
X=X+DE
PON=(X-B(NP1))/B(NP2)
PON2=PON*PON
AR=0.5*PON2
IF (AR -20.0) 2,3,3
2 P=CONS*EXP(-AR)*DE
A(I,NP1)=PON/B(NP2) + A(I,NP1)
A(I,NP2)=P*(PON2-1.0)/B(NP2) + A(I,NP2)
A(I,NP3)=P/B(NP3) + A(I,NP3)
FU(I)=FU(I)+P
3 CONTINUE
900 CONTINUE
800 CONTINUE
700 CONTINUE
DO 600 I=NS,NF
FC(I)=Y(I)-FU(I)
FA(I)=FC(I)+FA(I)
600 FIT=FIT+(FC(I)**2)/Y(I)
WRITE(LO,999)NP1,NP2,NP3,NMULT,AR,Y(NS),FU(NS),FC(NS),CONS,P,FIT,
C 1PON2,X
C 999 FORMAT(6H FUN 2,415,5E12.5/1X,4E12.5)

```



```

RETURN
END
IFOR,IS GANE
SUBROUTINE GANE (TZ,NX,GAIN,RQGAIN,SMOOTH,C)
C***** PROGRAM NUMBER - 17 CUGEL *****
C
C REF. JR. NUC. SCI. AND ENG. VOL 35, MAR. 1969 STEYN AND ANDREWS
C MARCH 1968 VERSION, I.E. DIMENSION CAPACITY CHECK
C GAIN CHANGING PROGRAM, ALSO SPECTRAL SHIFTING.
C
COMMON/GAN/NLI
DIMENSION C(200),FM(800)
NLIMIT=NLI
WONX=NX
ONX=(RQGAIN/GAIN)*WONX
NONX=ONX
IF (NONX-NLIMIT) 620,620,621
621 NX=NX-(NLIMIT-NONX)-1
620 IF (TZ) 600,601,601
600 JTZ=ABS(JTZ)
NX=NX-JTZ
IF (NX-NLIMIT) 601,601,603
603 NX=NLIMIT
601 IF (TZ) 1000,275,1000
1000 NZC=TZ
NXO=NX-NZC
C
C INTEGER SHIFT IF *NZC* NOT EQUAL TO ZERO.
C
IF (TZ) 913,910,911
913 NZC=NZC-1
NS=NZC*(-1) + 1
NSX=NS-1
NSXO=1
NXO=NSX+NX
955 DO 956 I=NS,NXO
K=I+NZC
956 FM(I)=C(K)
957 C(I)=FM(I)
GO TO 93
911 NS=1
NSXO=NXO-1
NSX=NSX
K=I+NZC
91 C(I)=C(K)
93 DO 92 I=NSXO,NSX
92 C(I)=0.0
910 NX=NXO
C
C DECIMAL SHIFT.
C
274 INZC=NZC
DIF=TZ-INZC
IF (DIF) 271,272,271
271 NXON=NX-2
DDIF=1.0-DIF
DO 270 I=2,NXON
C(I)=C(I)-C(2)*DIF
270 C(I)=C(I)*DDIF + C(1)*DIF
C(NXON+1)=C(NXON+1)*DDIF + C(NX)
GO TO 273
272 IF (INZC) 273,275,275
273 NX=NX-1
275 IZ=0.

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```

DEL=NX-X
109 IF (DEL-1.0) 111,111,110
110 DIF=DEL-1.0
DEL=DEL-DIF
GO TO 109
111 I=I+1
GO TO 106
202 DO 1999 INX=1,NLIMIT
1999 C(INX)=0.0
NX=NX
NX=NX/DE
NX=NX
C
C LOAD ODD CHANNELS IF *DELTA* EQUAL TO ZERO.
201 IF (DEL) 300,301,300
300 NC=2
ND=1
GO TO 302
301 NC=1
ND=0
302 DO 200 I=1,NX
J=NC+1-ND
200 C(J)=FM(I)
IF (DEL) 303,304,303
304 IF (I-1)/404, 500, 404
404 L=L-1
GO TO 496
C
C HALVING.
204 I=1
NCHECK=NX
NX=NX/2
NCR=NCHECK-(NX/NX)
IF (NCR) 555, 504, 555
555 NX=NX+1
504 K=2*I-1
C(I)=C(K)+C(K+1)
IF (I-NX) 502,503,503
502 I=I+1
GO TO 504
503 IF (I-1)/525,525,205
C
C SMOOTHING IF *SMOOTH* NOT EQUAL TO ZERO.
525 IF (SMOOTH) 526,500,526
526 DELT=DEL
SMOOTH=SMOOTH-1.0
FMULT=0.5
GO TO 496
205 L=L-1
GO TO 204
C
C COUNTS SCALED IN ACCORD WITH *FMULT* FOR INCREASED SPECTRA.
500 KK=0
915 CONTINUE
IF (KK) 1499,1500,1499
1500 FAC=1.0
GO TO 1501
1499 FAC=1.0/2.0**KK
1501 IF (FMULT-FAC) 916,917,917
916 KK=KK+1
GO TO 915
917 DO 920 I=1,NX

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920 C(I)=C(I)*FAC
IF (SMOOTH) 205,527,204
527 GAIN=G
RETURN
END
(FOR,IS GEOMTR
SUBROUTINE GEOMTR (ENXTAL,E,PHI,NS,NX,DE,DT,VOL,RX,RO)
C***** PROGRAM NUMBER - 18 CUGEL *****
C
C COMPUTES GEOMETRY FACTORS. INTEGRATES NUMBER AND ENERGY SPECTRA.
C CALCULATES NORMALIZED DOSE DATA FOR FINAL CODE RESULTS.
C
COMMON /C/ SUMNUM,SUMENY,DOSDET,AVENGY,PHNUBE,ENBENY,PHENBE,
1 DOSBEX,DOSCYL,DBXVOL,DCYVOL,BETNUM,BETENY,CYLDIA
DIMENSION PHI(400),E(400),ENXTAL(400)
PIE=3.14159265
VOL=(PIE*CYLDIA**3)/4.0
TIME=DT*60.0
AREAT=PIE*RX*RX
CONST=3600./5.24E+07
SUMNUM=0.0
SUMENY=0.0
SOGEOM=0.5*(1.0-RO/SORT(RO*RO+RX*RX))
DOSDET=0.0
C INTEGRATE.
DO 2 I=NS,NX
PHI(I)=DE*PHI(I)/(AREAT*TIME)
ENXTAL(I)=PHI(I)*E(I)
EC=E(I)
DOSXTL = PHI(I)*CONST*DOSE (EC)
SUMNUM=SUMNUM+PHI(I)
SUMENY=SUMENY+ENXTAL(I)
2 DOSDET=DOSDET+DOSXTL
C
AVENGY=SUMENY/SUMNUM
PHNUBE=SUMNUM/BETNUM
ENBENY=SUMENY/BETENY
PHENBE=SUMENY/BETNUM
DOSBEX=DOSDET/BETNUM
DOSCYL=DOSBEX/SOGEOM
DBXVOL=DOSBEX/VOL
DCYVOL=DOSCYL/VOL
C
RETURN
END
(FOR,IS GUESS3
SUBROUTINE GUESS3(NS,NFN,Y,B,V1,V2)
C***** PROGRAM NUMBER - 19 CUGEL *****
C
C DOUBLE PHOTOPEAK INITIAL PARAMETER ESTIMATES
C
COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
DIMENSION B(8),Y(400),VT(50)
AREAT=0.0
I1=0
I1=0
XNS=NS
XNF=NFN
B(I7)=(Y(NFN)-Y(NS))/(XNF-XNS)
NT=NS
IF (I7) 25,26,25
25 NI=1
NV1=V1
NV2=V2
DO 100 I=NV1,NV2
J=I-NV1+1
100 VT(J)=1.0/Y(I)

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```

N2=J
CALL VECTMX(VT,N1,N2,JMAX,BIG)
II=JMAX-NV1-1
IF(II-NV1)105,105,105
106 IF(II-NV2)26,105,105
105 IF(V1-V2)/2.0*1.0
26 DO 3000 I=NS,NFN
X=J-NS
AREAT=AREAT-Y(I)-Y(NT)*X*B(7)
IF(I-1)50,50,3000
50 A1=AREAT
3000 CONTINUE
B(3)=A1
B(6)=AREAT-A1
B(8)=Y(NS)
IF(MOUT)2,1,2
1 WRITE(LO,10)(B(I),I=1,8)
10 FORMAT(8H GUESS3 /IX,8E14.7)
2 RETURN
END
(FOR,IS PKFUN
SUBROUTINE PKFUN (NX,NPK,NFREE,J,NSS,NFNN,NPARA,E,FM,B,TITLE)
C***** PROGRAM NUMBER - 20 CUGEL *****
C
C PHOTOPEAK FITTING CONTROL
C
C DIMENSION TITLE(2),FM(800),NPARA(8),B(8),FA(80),A(5)
COMMON/LIO/LIO,LO,LP,NLIMIT,NORM,MOUT
NPS=3*NPK*1
NPI=NPK*3*2
WRITE(LO,2)JNS,(NPARA(I),I=1,5),E
B2=0.00128*EXP(0.395*E)
B2=B2*1.2
ANS=NS
BX=B2*ANS/E
N1=ANS-6.*BX-0.5
N2=ANS*6.*BX+0.5
CALL VECTMX (FM,N1,N2,JMAX,YMAX)
YMAX=YMAX-((FM(N2)+FM(N1))/2.0)
B(1)=JMAX
B(2)=B2*B(1)/E
B(3)=YMAX*B(2)*2.35
WRITE (LO,7) NSS,NFNN,B(1),B(2),B2,YMAX
C
C WRITE(LO,7)N1,N2,BX,ANS,B(2),B(3)
SS=B(1)-6.0*B(2)-0.5
FMN=B(1)+6.0*B(2)+0.5
NSS=SS
NFNN=FMN
WRITE(LO,7)NSS,NFNN,SS,FMN,B2,B(3)
C
C 7 FORMAT(8H PKFUN 2,215,4E14.7)
WRITE(LO,5)(B(I),I=1,NPI)
XNF=NFNN-NSS*1
B(NPI)=FM(NSS)
B(NPS)=(FM(NSS)-FM(NFNN))/(-XNF)
NAS=NSS
DO 31 K=1,2
IF(K-1)30,30,22
22 IF(FM(NSS)-0.8*FM(JMAX))20,21,21
20 NSS=NSS+1
GO TO 22
21 CONTINUE
A(1)=B(1)
A(2)=B(2)
A(3)=B(3)
A(4)=B(4)
A(5)=B(5)

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```

JMIN=JMIN
N=2
GO TO 7
C GO TO 4 FOR GENERAL INTERPOLATION
4 MIN1=JMIN
MIN2=JMIN+1
MIN3=JMIN+2
N=3
EX=E
EXB=E/(1.0*(E/O.S11)*2.0)
EXCE=EXB
7 DO 46 J=1,NORM
44 FM(1)=R(I,MIN3)
WRITE(LO,502) MIN1,MIN2,MIN3,JMIN,NSIG,MSIG,NY,NSTAND,EXB,EX,EXC,EXC,E
DO 40 J=1,3
JJ=J+MIN1-1
ECE(J)=STDEN(JJ,1)-EBS(JJ)
WRITE(LO,500) JJ,STDEN(JJ,1)
40 VCE(J)=ECE(J)*NORM/STDEN(JJ,1)
WRITE(LO,104) (EBS(I),I=MIN1,MIN3)
WRITE(LO,104) (ECE(I),I=1,3)
WRITE(LO,104) (VCE(I),I=1,3)
N1=VCE(3)-0.05*VCE(3)
N2=VCE(3)+0.05*VCE(3)
CALL VECTMX(FM,N1,N2,JMAX,YMAX)
NCE(3)=JMAX
FNCE=NCE(3)
FNCE=FNCE/VCE(3)
DO 45 J=1,2
45 VNCE(J)=VCE(J)*FNCE
VNCE(3)=VCE(3)
NCE(1)=VNCE(1)+0.5
NCE(2)=VNCE(2)+0.5
DO 81 I=1,NORM
81 FM(I)=0.0
WRITE(LO,503) (NCE(I),I=1,3),N1,N2,JMAX,EXC
C C C
CHANGE FIRST HALF OF STANDARD CONTINUA
DO 46 J=1,3
DO 46 I=1,NORM
46 RC(1,J)=0.0
NVX(3)=NCE(3)*20
DO 48 J=1,2
GAIN=VNCE(J)
RGAIN=VNCE(3)
NX=NVX(3)
JJ=J+MIN1-1
DO 49 I=1,NX
49 FM(I)=R(I,JJ)
MX=NX
WRITE(LO,1000) NVX(3),NX,GAIN,RQGAIN
CALL GANE(TAZ,MX,GAIN,RQGAIN,SM,FM)
NVX(J)=NX
DO 50 I=1,NX
50 (I,J)=FM(I)
51 I=1,NORM
51 J=0.0
DO 52 I=1,101
52 NVX(I)=NVX(2)+NX*N VX(3),MX,J

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READ(I,88)ALABEL(J),BLABEL(J),STDEN(J,1),STDEN(J,2),ENSJ,50,SKJ,F
1XJ,ENC,S,SHIFT(J),(R(I,J),I=1,NXLIM)
88 FORMAT(2A3,8F6.0/(10F7.0))
R(NXLIM,J)=1.0
NSJ(J,1)=ENSJ
NSXJ(J)=SKJ
NFXJ(J)=FXJ
ISO(J)=SO
NCS(J)=ENC
8080 CONTINUE
C
C COMPLEMENT OVERSUBTRACTED COUNTS.
DO 8000 J=1,NSTAND
DO 8000 I=1,NXLIM
IF(R(I,J)-190) 8001,8001,8002
8002 R(I,J)=R(I,J)-T100
8001 CONTINUE
8000 CONTINUE
C
C3456 WRITE(LO,3456)N,M,REPEAT,EM,ELIMIT,ESING
C3456 FORMAT(10H SHAPE=1 ,215,5X,3E14.7)
C
C SHIFT SPECTRA AN AMOUNT TZ IF TZ NOT =0
NTZ=0
DO 9000 J=1,NSTAND
IF( SHIFT(J))9001,9002,9001
9001 TZ= SHIFT(J)
NTZ=TZ
IF(NSXJ(J))9018,9019,9018
9018 NSXJ(J)=NSXJ(J)-NTZ
NFXJ(J)=NFXJ(J)-NTZ
9019 NSJ(J,1)=NSJ(J,1)-NTZ
NCS(J)=NCS(J)-NTZ
NXLIM
GAIN=1.0
ROGAIN=1.0
DO 9003 I=1,NXLIM
FM(I)=R(I,J)
9003 R(I,J)=0.0
CALL GAME (TZ,NX,GAIN,ROGAIN,SM,FM)
DO 9004 I=1,NX
9004 R(I,J)=FM(I)
9002 CONTINUE
9000 CONTINUE
DO 7002 J=1,NSTAND
NPHA=NCS(J)
DO 7002 I=1,NPHA
7002 R(I,J)=R(NPHA ,J)
C SUBTRACT X-RAY PEAKS, ETC.
C
DO 5001 J=1,NSTAND
IF (NSXJ(J),NFXJ(J))5029,5001,5029
5029 DEL=NFXJ(J)-NSXJ(J)
NXX=NSXJ(J)
NSX=NSXJ(J)+1
NFX=NFXJ(J)
NFX=NFXJ(J)-1
DO 5021 I=NSX,NFX
N=I-NXX
5021 R(I,J)=R(NXX,J)+N*(NFXJ(J)-R(NXX,J))/DEL
5001 CONTINUE
UNGAIN=0.0
WRITE(LO,7) NSTAND,NPHA,UNGAIN, (ALABEL(J),
1BLABEL(J),NSJ(J,1),NSXJ(J,2),NSXJ(J),SHIFT(J),STDEN(J,1),
2STDEN(J,2),J=1,NSTAND)
7 FORMAT(1H1,15X ,3TH STANDARD SOURCE SPECTRAL PARAMETERS ,///

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1 14X,15,33H SPECTRA IN STANDARD SOURCE DECK ,//
2 13X,16H CHANNELS ONE TO ,14,22H ASSUMED AS REDUNDANT ,//
3 17X,25H REFERENCE COARSE GAIN = ,F10.5,////
41X,72HSTANDARD PHOTOPEAK X-RAY OR .5 PEAK SHIFT TO
5 PHOTOPEAK ,73H SOURCE FROM CHANNEL CHANNEL
6 SPECTRUM ENERGIES //10X,70H MEV MEV
7 CHANNEL CHANNELS MEV MEV
8 (2X,2A3,6X,14,5X,14,7X,13,6X,13,4X,F9.4,1X,2F10.5)
DO 27123 J=1,NSTAND
WRITE (LO,8999) ALABEL(J),BLABEL(J),(R(I,J),I=1,NXLIM)
8999 FORMAT (1H1,32X,25H STANDARD SOURCE SPECTRA ,////// 3X,2A3,
1 RH SOURCE ,////(1X,10F9.0))
27123 CONTINUE
WRITE (LO,3)
3 FORMAT (1H1)
C
C CALL SPNORM TO CALC GAUSSIAN PARAMETERS AND UNIT CONTINUA FOR STANDS.
C
C CALL SPNORM
C
IF(ICO)607,607,608
607 ICY=NSTAND-NA00
GO TO 609
608 ICY=ICO-1
609 CONTINUE
C 930 WRITE(LO,930)ICY,ICO,(NCS(I),I=1,12)
C 930 FORMAT(11H NCS CHECK ,14I4)
CALL BS(ICY,1,M3)
IF(ICO)24,20,24
24 NSIG=2
E=STDEN(ICO,2)
JMIN=ICO-3
WRITE(LO,100)ICO,NSTAND,STDEN(ICO,2)
C
C CALL POGELI (FOUT,NSIG,MSGIG,JMIN,E,CEA,DEA)
C
NXL=NXLIM
DO=DEA*NXL/ORM
PARAV(ICO,2)=PARAV(ICO,2)-DO
PARAV(ICO,1)=PARAV(ICO,1)-DO
TITLE(1)=ALABEL(ICO)
TITLE(2)=BLABEL(ICO)
CALL XPLOT(TITLE,FOUT,FOUT,1,NORM)
WRITE(LO,200)(FOUT(I),I=1,NORM)
A3=NORM*PARAV(ICO,2)/PARAV(ICO,1)
MX=NORM +1
GAIN=NORM
ROGAIN=A3
N3=A3+1
DO 9090 I=1,NORM
9090 FM(I)=FOUT(I)
CALL GAME(TAZ,MX,GAIN,ROGAIN,SM,FM)
DO 9091 I=1,NORM
9091 FOUT(I)=FM(I)
WRITE(LO,200)(FOUT(I),I=1,200)
DO 910 I=1,N3
910 FOUT(I)=FOUT(I)*PAREA(ICO,2)
WRITE(LO,100)MX,N3,ROGAIN
C
WRITE(LO,412)(FOUT(I),I=1,NORM)
WRITE (LO,100)ICO,NXLIM,DO
DO 911 I=1,NXLIM
FM(I)=R(I,ICO)
911 R(I,ICO)=0.0
WRITE (LO,412) (FM(I),I=1,NXLIM)
MX=NXLIM

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COMMON/RES/R,N,ENDUM(2),NDEG,DUM1(480),K,MHP,DUM2(2)
COMMON/SOL/RES/EPSS,IT,ITMAX,MN,DUM3(2),DIF,SIGMA(12)
COMMON/LIO/LI,LO,LP,NLIMIT,NORM,MOUT
DIMENSION PP( 50),P(800),R( 40),PHI(400),FIT(100),DIF(100)
1,MN(18)
C
C INITIALIZE
C
NCHECK=ITMAX/2
NCHECK=ITMAX-2*NCHECK
SUM=0.0
DO 1999 I=K,N
SU=SU + P(I)
1999 SU=SU + P(I)
DO 1800 I=K,N
1800 P(I)=P(I)/SU
YMAX=0.0
C
CALL VECTMX (P,K,N,JMAX,YMAX)
C
C
YLOW=YMAX*(1.0E-15)
DO 1 I=1,N
PP(I)=0.0
1 PHI(I)=P(I)
WRITE IF ITMAX IS AN ODD-NUMBER.
IF (NCHECK) 8999,8000,8999
8999 WRITE (LO,9899) (P(I),I=1,N)
8999 FORMAT (30H1 NORMALIZED INPUT SPECTRUM
INDEX=1
8000 CONTINUE
IT=1
FIT(I)=0.
C
C MATRIX MULTIPLICATION PER PHI
C
DO 2 I=K,N
PP(I)=0.0
DO 2 J=K,N
IF (R(I,J)) 2001,2000,2001
2001 PP(I)=PP(I) + R(I,J)*PHI(J)
2000 CONTINUE
2 CONTINUE
TERM = 0.0
C
C ARRESTING CHECK WHEN DIF(SUM(P-PP)**2/P) FOR LOOP(IT) AND LOOP(IT-1)
C ARE LESS THAN EPS.... OR IT=ITMAX.
C
DO 5 I=K,N
IF (P(I)) 4,6,4
4 TERM = (PP(I) - PP(I))**2/P(I) * TERM
6 CONTINUE
5 CONTINUE
IF (NCHECK) 16000,15000,16000
16000 IF (MN(INDEX) - IT) 15000,17000,15000
17000 WRITE(LO,19000) IT,MN(INDEX),PHI(I),I=K,N
WRITE(LO,19005) IT,MN(INDEX),PP(I),I=K,N
INDEX=INDEX+1
15000 CONTINUE
19000 FORMAT (51H INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PHI(I)) 215
1/ (1X,10E11.4))
19005 FORMAT (51H INTERMEDIATE ITERATING OUTPUT (IT, MN, AND PP(I)) 215
1/ (1X,10E11.4))
IT=IT+1
FIT(IT)=TERM
DIF(IT)=ABS (FIT(IT-1) - FIT(IT))
IF ( DIF(IT)
29 IF (IT-ITMAX) 229,7,7
- EPS) 7,7,29

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C
C SCOFIELD CORRECTION FACTOR METHOD.
C
229 DO 25 I=K,N
  IF (PP(I)) 125,52,125
125 PHI(I)=PHI(I)*P(I)/PP(I)
52 CONTINUE
25 CONTINUE
DO 1000 I=K,N
  IF (ABS(PHI(I)) - YLOW) 1001,1002,1002
1001 PHI(I)=0.0
1002 CONTINUE
1000 CONTINUE
GO TO 10
C
C RESULTS.
C
7 DO 600 I=K,N
  P(I)=P(I)*SU
600 PHI(I)=PHI(I)*SU
C WRITE IF ITMAX IS AN ODD-NUMBER.
  IF (NCHECK) 9999,10000,9999
9999 WRITE (LO,9998) (PP(I),I=1,N)
9998 FORMAT (20H ITERATED SPECTRUM
10000 CONTINUE
60 FORMAT (20H0 IT,SU,TERM
  WRITE (LO,60) IT,SU,TERM
  RETURN
END
C
C FOR IS SIMPSN
  FUNCTION SIMPSN (A,B,EPS)
  C***** PROGRAM NUMBER - 24 CUGEL *****
C
C SIMPSONS RULE INTEGRATING PROGRAM FOR FUNCTION -FC-.
C
COMMON /B/ KL,UEGAM,IX,DIST,M
TMAX=2048.
AN=2.0
FA=FC(A)
FB=FC(B)
FP=0.0
SI=0.0
DELT=B-A
405 FOUR=0.0
  AK=1.0
  AKNE=AN/2.0
399 FFA=FC(A*((2.0-AK-1.0)*UELT)/ANI)
  FOUR=FOUR+FFA
  IF (AKN-AK) 400,401,400
  GO TO 399
400 AK=AK*1.0
401 SIN=(UELT/ANI*(3.0))*((FA+FB+4.0*FOUR+2.0*FP)
  IF (ITMAX-ANI) 503,503,499
499 DIFX=ABS(SIM-SI)
  IF (EPS-DIFX/SIM) 402,403,403
402 AN=AN*AN
  FP=FP+FOUR
  SI=SI+
  GO TO 405
503 CONTINUE
403 SIMPSN=SIM
  RETURN
END
C
C FOR IS SOLN
  SUBROUTINE SOLN (NS,PHI,P,ETA,DIST,M,IX,TKLUM,PFRAC,M19)
C***** PROGRAM NUMBER - 25 CUGEL *****
C
DETERMINES AND APPLIES DETECTOR EFFICIENCY VECTOR.
C
COMMON /A/ DI,M,MF
COMMON /RES/R,N,DUM(2),NUMUN,E,DUM2(80),K,MHDUM,DUM3(2)
COMMON /SOLRES/EP5,IT,ITMAX, MN,MSKIP,M14,DIF ,SIGMA(12)
COMMON /LIO/LI,LO,LP,NLIMIT ,NORM,MOUT
DIMENSION P1800(140),PHI(140),ETA(400),E(400),DIF(100),M(24)
1 MN(18) ,PFRAC(40)
MF=0
IF (K) 50,30,50
30 K=1
50 KK=K-1
  IF (KK-1) 601,602,602
602 DO 600 I=1,KK
600 P(I)=0.0
601 CONTINUE
  IF (M(5)) 12,11,12
C
11 CALL RESMAT (PHI,P)
  WRITE (LO,1424) (DIF(I),I=1,IT)
1424 FORMAT (30H FITTING DIFFERENCES
/ (IX,SE14.7) )
C
12 IF (DIST-DI) 3,40,3
40 IF (MSKIP) 3,4,3
3 IF (M(14)) 2,13,2
C
13 CALL DETECT (NS,N,E,M,ETA,DIST,RX,TKLUM,PFRAC,M19)
C
2 DI=DIST
4 IF (M(14)) 54,44,54
44 DO 22 I=NS,N
22 PHI(I)=PHI(I)/ETA(I)
MF=0
C WRITE DIF(I) IF (IT=ITMAX)
  IF (IT=ITMAX) 89,100,100
100 WHITE(LO,105) (DIF(I),I=1,IT)
105 FORMAT (1H,36H FLUX FITTING DIFFERENCES (IT=ITMAX)/(IX,SE14.7) )
89 RETURN
54 IF (M(15)) 98,99,98
98 DO 96 I=NS,N
96 ETA(I)=1.0
99 DO 999 I=NS,N
999 PHI(I)=P(I)/ETA(I)
MF=1
  RETURN
END
C
C FOR IS SPNORM
  SUBROUTINE SPNORM
  C***** PROGRAM NUMBER - 26 CUGEL *****
C
C CALLED BY *RESFUN* TO NORMALIZE STANDARD SPECTRA
C FITS GE(LI) PHOTOPEAKS. NORMALIZES COMPTON CONTINUA
C
DIMENSION H(400,12),ALABEL (12),BLABEL(12),STOEN(12,2),
1PARAV(12,2),PARAS(12,2),PAREA(12,2),ISO(12),NCODE(12),
2NPARA(8),H(8),TITLE(2),NSJ(12,2),NFNJ(12,2),FM(800)
COMMON /LIO/LI,LO,LP,NLIMIT,NORM,MOUT
COMMON /SPN/H,STOEN,B,PARAV,PARAS,PAREA,ALABEL,BLABEL,
1NSJ,NFNJ,NSTAND
COMMON /ALIM/NXLIM,IS,INZ,INA,ICO,124,150
COMMON /GAN/NLI
NLI=800
NFNO=NLIMIT
NFNO=NFXNO-1
INZ=0
C

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```

INZ=0
INA=0
IC0=0
I2=0
DO 1 J=1,12
1 NCODE(J)=0
DO 2 J=1,NSTAND
IF (ISU(J)-85)4,3,4
3 I5=J
NCODE(J)=1
GO TO 14
4 IF (ISU(J)-65)7,5,7
5 IF (I5)6,7,6
6 INZ=J
NCODE(J)=2
GO TO 14
7 IF (ISU(J)-22)10,8,10
8 IF (I5)9,10,9
9 INA=J
NCODE(J)=3
GO TO 14
10 IF (ISU(J)-60)12,11,12
11 IC0=J
NCODE(J)=4
GO TO 14
12 IF (ISU(J)-24)14,13,14
13 I24=J
NCODE(J)=5
14 CONTINUE
2 CONTINUE
C 300 WHITE(10,300)15,INZ,INA,IC0,I24,(ISU(J),J=1,12),(NCODE(J),J=1,12)
C 300 FORMAT(1X,30I3)
C
NFWEE=3
NPK=1
NPARA(1)=1
NPARA(2)=2
NPARA(3)=3
NPARA(4)=0
NPARA(5)=0
DO 16 I=1,2
DO 15 J=1,NSTAND
JJ=J
E=STOEN(J,I)
IF (I-2)18,17,18
17 IF (E)200,200,217
200 NFNN=0
NFNN=0
B(1)=0.
B(2)=0.
B(3)=0.
GO TO 219
217 NSJ(J,I)=PARAV(J,I)*E/STOEN(J,I)
18 CONTINUE
DO 19 K=1,NKLI
19 FM(K)=R(K,J)
NS=NSJ(J,I)
TITLE(1)=ALABEL (J)
TITLE(2)=BLABEL (J)
CALL PKFUN(NKLI,1,3,JJ,NS,NS,NFNN,NPARA,E,FM,B,TITLE)
DO 199 K=1,NKLI
199 R(K,J)=FM(K)
219 NSJ(J,I)=NS
NFNN(J,I)=NF
PARAV(J,I)=R(1)
PARAS(J,I)=R(2)

```

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```

PAWEA(J,I)=H(3)
15 CONTINUE
16 CONTINUE
C
C SUBTRACT 51 COMPONENTS FROM ZN65 AND NA22
C
IF (I5)20,21,20
20 IF (INZ)27,23,27
27 I0=INZ
22 NF=NKLI
DO 24 I=1,NF
24 FM(I)=R(1,I5)
GAIN=PARAV(15,1)
ROGAIN=PARAV(10,2)
SM=0.0
TAZ=0.0
CALL GANE (TAZ,NF,GAIN,ROGAIN,SM,FM)
NOF=NF/J(10,2)+1
NSF=NSJ(10,2)-1
DF=NOF-NSF
NAF=NOF-1
SLO=(R(NOF,10)-R(NSF,10))/DF
DO 25 I=1,NAF
25 R(1,I)=R(1,I0)-FM(1)*PAWEA(10,2)/PAREA(15,1)
NOSF=NSF+1
DO 26 I=NOSF,NOF
26 R(1,I)=R(NSF,10)*SLO*X
23 IF (INA)37,21,37
37 I0=INA
GO TO 22
21 CONTINUE
C
C NORMALIZE CONTINUA (CEPT C060 AND NA24) FOR GAIN AND COUNT
C
DO 7010 J=1,NSTAND
SUM=0.0
SAM=0.0
IF (NCODE(J)-3)30,30,31
DO 7003 I=1,NLIMIT
30 SAM=SAM+R(1,I,J)
FM(1)=R(1,J)/PAREA(J,1)
SUM=SUM+FM(1)
7003 R(1,J)=0
GAIN=PARAV(J,1)
NX=NLIMIT
SUMP=PAWEA(J,1)/(SAM*PAREA(J,1))
IF (GAIN-100.0)991,992,9992
991 NX=(200.0*GAIN/100.0)-1.0
9992 NF=GAIN+1.0
C WRITE(10,818)J,NX,NF,NOF,NAF,SUMP,SUM,SAM,DF,R(20,J),(FM(1)
C 11),I1=1,NLIMIT)
C 818 FORMAT (10H RESGEN 1 /1X,5I5,5X,5E14.7/(1X,5E14.7))
TAZ=0.0
SM=0.0
ROG=NORM
CALL GANE (TAZ,NX,GAIN,ROG,SM,FM)
SIM=0.0
DO 30000 I=1,NLIMIT
30000 IF (FM(1))30001,30002,30002
30001 NF=NOMH=1-1
30002 CONTINUE

```

```

30000 CONTINUE
C ZERO FROM THE FIRST NEGATIVE CHANNEL TO 260
11004 DO 30509 I=NFO,NLIMIT
30509 FM(I)=0.0
DO 7004 I=1,NLIMIT
SUM=SUM+FM(I)
7004 R(I,J)=FM(I)
C WHITE(ILO,225)SUM
C 225 FORMAT(7H SUM = ,E14.7)
31 CONTINUE
7010 CONTINUE
DO 32 I=1,2
WHITE(ILO,H20)(J,ALABEL(J),ALABEL(J),PARAV(J,I),PARAS(J,I),PAREA(J,
11),J=1,NSTAND)
R20 FORMAT(1H1,45X,20HRESULTS OF PHOTOPEAK FITTING ///
1 8X,5HINDEX,12X,15HSTANDARD SOURCE,11X,12HPULSE=HEIGHT,10X,
2 10HSTANDARD DEVIATION,14X,4HAREA/ 52X,10H(CHANNELS),15X,
3 10HCHANNELS,14X,13H(COUNTS/TIME)///(9X,13,18X,2A3,3X,3E25,7))
32 CONTINUE
RETURN
END
(IFOR,IS STDFIT)
SUBROUTINE STDFIT(YI,YB,NFNN,NSS,NFREE,NPK,NPARA,NAS,FA,TITLE,JUMP)
C***** PROGRAM NUMBER - 27 CUGEL *****
C
C NON-LINEAR REGRESSION PROGRAM FOR PHOTOPEAKS
COMMON/LIO/LI,LO,LP,NLIMIT,NOMM,MUOT
COMMON/FUN/A(180),Y(160),FC(80),FU(80),FIT,DN,DNN,NS,NFN,ND,MP
DIMENSION Y(1800), NPARA(8),B(8), G(9,9),FA(80),TITLE(2)
MP=0
IC1=0
IF (JUMP) 5058,5058,5059
5059 B1=NAS
B4=B(1)
B(1)=B(1)-d1
NSS=NAS
5058 CONTINUE
A2=B(2)
A3=B(3)
458 NS=1
NFNN=NFNN+NSS+1
XNNS=NS
DO 500 I=NS,NFN
500 Y(I)=YY(I)*NSS-1
DO 502 I=NS,NFN
IF(Y(I)) 503,503,502
503 Y(I)=1.0
502 CONTINUE
NPS=3+NPK+1
NFI=NPS+1
IF (JUMP) 6050,6050,6051
6050 ND=1
NSFDIF=NFNN-NS+1
XNF=-NSFDIF
52 IF (NSFDIF-50) 51,5050,5050
51 ND=2*ND
NSFDIF=NSFDIF+NSFDIF
GO TO 52
5050 DNN=ND
DN=1.0/(2.0*DNN)
6041 IF (JUMP) 5055,5055,5056
5056 CALL FUNZ(NPK,B,FA)
GO TO 42
5055 EPS=0.00001
NT=15

```

```

L=0
WHITE(ILO,5000)NS,NFN,NPS,NP1,ND,NSFDIF,UNN,UN,XNF,B(NP1),B(NPS)
C5000 FORMAT(9H STDFIT 1,615,5E14.7)
5 CALL FUNZ(NPK,B,FA)
1011 DO 58 J=1,NFREE
NAPENPARA(J)
B(J)=B(NAPN)
DO 58 K=1,NFN
58 ATK+J)=ATK,NAPN)
C CONSTRUCT THE NORMAL EQUATIONS
MENFREE+1
DO 21 I=1,NFREE
G(I,M)=0.0
DO 21 J=NS,NFN
21 G(I,M)=G(I,M)+A(J,I)*FC(J)/Y(J)
DO 22 I=1,NFREE
DO 22 K=1,NFREE
G(I,K)=0.0
DO 22 J=NS,NFN
22 G(I,K)=G(I,K)+A(J,I)*A(J,K)/Y(J)
C SOLVE NORMAL EQUATIONS FROM HERE TO STATEMENT 11
K=1
100 IF(K-NFREE)2,2,18
2 J=K+1
101 IF(J-M)3,3,44
3 IF(G(K,K))4055,4056,4055
4056 G(K,K)=1.0E-10
4055 G(K,J)=G(K,J)/G(K,K)
J=J+1
GO TO 101
4 I=K+1
102 IF(I-NFREE)7,7,6
6 K=K+1
GO TO 100
7 J=K+1
103 IF(J-M)17,17,16
16 I=I+1
GO TO 102
17 G(I,J)=G(I,J)-G(I,K)*G(K,J)
J=J+1
GO TO 103
18 K=NFREE
15 IF(K-1)11,10,10
10 I=1
14 IF(I-K)12,13,12
12 G(I,M)=G(I,M)-G(I,K)*G(K,M)
I=I+1
GO TO 14
13 K=K-1
GO TO 15
11 CONTINUE
C FIT ARRESTING CHECK
L=L+1
IF(L-1)29,29,29
28 IF(ABS(FITM1-FIT)/FIT)42,42,29
29 IF(L-NI)8,42,42
8 DO 24 I=1,NFREE
24 B(I)=B(I)+G(I,M)
IF(H(2))60,60,61
60 H(2)=42
61 IF(H(3))62,62,63
62 H(3)=43
63 CONTINUE
C WHITE(ILO,5432)L,C1,G(I,M),J=1,5)
C5432 FORMAT(4H n-Check ,2110,5E14.7)
IF(M-1)756,456,457

```



APPENDIX III

SAMPLE INPUT CARD DECK LISTING

1.0  
TEST RUN WITH RESFUN GROUP  
0 0 3 0 0 0 7 0 9 0 0 0 0 0 16 17 0 0 0 0 0 0 0  
2.755 1.0 1.0 40.0 51. 89. 0.0 1.63 3.1

8 400 1  
CE139 .166 0.0 358. 1.9.  
-133. -447. -791. -667. -233. 466. 1104. 1508. 1955. 2251.  
2385. 2696. 2970. 3081. 3382. 3577. 3692. 3670. 3931. 4043.  
4344. 4467. 4465. 4718. 4815. 4891. 4898. 5042. 5087. 5236.  
5218. 5348. 5470. 5480. 5618. 5436. 5583. 5634. 5775. 5696.  
5857. 6113. 5865. 6019. 6003. 6175. 6346. 6467. 6526. 6888.  
6988. 7238. 7704. 8105. 8442. 8896. 10588. 11662. 12650.  
14341. 15744. 16374. 16364. 15429. 13640. 11493. 9071. 7215. 5814.  
5353. 5088. 5173. 5022. 5090. 4430. 3718. 3066. 2373. 1814.  
1350. 1097. 850. 790. 802. 750. 772. 785. 790. 790.  
753. 833. 833. 780. 785. 803. 779. 795. 785. 793. 725.  
779. 765. 830. 895. 822. 829. 805. 816. 817. 843.  
863. 865. 850. 838. 877. 866. 881. 840. 894. 811.  
889. 866. 856. 862. 753. 845. 863. 845. 823. 769.  
704. 745. 731. 675. 687. 799. 595. 546. 487. 490.  
452. 479. 435. 411. 389. 413. 370. 387. 402. 361.  
409. 392. 363. 361. 416. 395. 424. 404. 374. 316.  
330. 394. 337. 364. 414. 415. 341. 388. 323. 338.  
350. 353. 400. 391. 316. 362. 359. 341. 406. 366.  
421. 365. 392. 401. 432. 449. 408. 458. 387. 375.  
365. 399. 396. 438. 426. 489. 453. 548. 494. 486.  
549. 568. 595. 562. 599. 686. 709. 889. 1007. 889.  
1014. 1138. 1255. 1365. 1462. 1430. 1490. 1480. 1466. 1452.  
1330. 1373. 1282. 1227. 1125. 1110. 961. 1023. 961.  
859. 877. 856. 868. 866. 833. 795. 776. 739. 747.  
798. 793. 834. 823. 807. 858. 828. 770. 807. 838.  
833. 812. 906. 852. 872. 829. 827. 743. 819. 805.  
782. 799. 787. 727. 822. 740. 730. 765. 752. 713.  
767. 677. 666. 651. 645. 613. 665. 637. 593. 630.  
557. 615. 614. 548. 599. 541. 556. 513. 542. 538.  
589. 574. 531. 557. 570. 602. 491. 530. 600. 563.  
603. 572. 534. 567. 568. 566. 572. 542. 573. 571.  
592. 567. 598. 535. 584. 606. 556. 611. 625. 614.  
612. 574. 630. 637. 578. 656. 610. 683. 596. 633.  
631. 616. 745. 627. 665. 632. 721. 718. 694. 725.  
706. 734. 778. 758. 769. 807. 870. 1082. 1375. 2217.  
3749. 6936. 11275. 17899. 25589. 33364. 37937. 40357. 37755. 32225.  
24148. 16654. 10329. 5766. 2847. 1238. 516. 158. 72. 8.  
8. -17. 7. -4. 8. -2. 0. 14. -12. -6. 1.  
-2. -1. 2. -7. 14. 14. -10. 9. 11.

HG203 .279 0.0 381. 203.  
0. 0. 0. 9. 83. 0. 0. 0. 0. 0.  
0. 0. 0. 392. 435. 468. 385. 428. 372. 392. 390. 448.  
349. 414. 402. 397. 353. 416. 337. 353. 408. 344. 364.  
406. 401. 400. 388. 345. 325. 332. 345. 315. 328.  
401. 374. 350. 326. 407. 338. 397. 338. 347. 308.  
354. 329. 378. 381. 328. 324. 339. 314. 367. 367.  
363. 327. 366. 364. 366. 356. 368. 432. 406. 406.  
435. 441. 493. 410. 458. 490. 446. 493. 460. 456.  
437. 499. 590. 629. 835. 1077. 1337. 1764. 2072. 1976.  
1796. 1326. 910. 596. 402. 338. 375. 333. 303. 471.  
517. 644. 721. 815. 651. 584. 511. 455. 386. 347.  
287. 283. 291. 196. 335. 237. 299. 255. 331. 371.  
307. 274. 314. 217. 227. 271. 269. 251. 319. 314.  
224. 268. 247. 256. 358. 269. 235. 269. 372. 341.  
308. 331. 311. 292. 242. 284. 276. 316.

328.	281.	322.	328.	419.	292.	380.	343.	370.	333.
330.	339.	420.	419.	409.	363.	417.	463.	441.	470.
504.	555.	595.	540.	559.	587.	527.	562.	489.	464.
504.	536.	494.	490.	433.	428.	445.	467.	353.	287.
266.	316.	302.	263.	263.	256.	217.	207.	223.	212.
228.	224.	192.	257.	156.	216.	215.	239.	197.	183.
165.	185.	193.	200.	188.	146.	167.	176.	183.	187.
186.	46.	148.	139.	121.	131.	145.	147.	161.	147.
137.	114.	103.	103.	146.	142.	115.	109.	126.	80.
148.	94.	111.	111.	92.	93.	85.	81.	72.	78.
93.	70.	95.	81.	59.	113.	69.	57.	96.	82.
49.	101.	74.	46.	86.	54.	94.	104.	68.	56.
93.	51.	41.	106.	63.	66.	84.	63.	75.	52.
66.	69.	72.	48.	67.	64.	99.	85.	93.	55.
32.	74.	46.	70.	95.	82.	57.	84.	71.	80.
71.	56.	68.	67.	82.	83.	47.	53.	100.	75.
73.	100.	66.	53.	62.	97.	64.	53.	93.	59.
49.	58.	60.	77.	82.	90.	61.	95.	83.	92.
49.	62.	95.	99.	84.	105.	42.	73.	64.	62.
72.	54.	83.	86.	65.	42.	61.	78.	84.	86.
58.	53.	91.	74.	81.	74.	90.	80.	88.	70.
94.	122.	129.	154.	315.	906.	1950.	3958.	6245.	7493.
7127.	4908.	2644.	1090.	358.	97.	39.	6.	4.	21.
-19.	-28.	0.	0.	14.	9.	1.	17.	14.	-3.
5885.	514.	0.0	89.	40.	108.	26.	0.0	0.	0.
0.	0.	0.	0.	0.	161.	1445.	1673.	1701.	1877.
0.	18.	18.	228.	708.	1913.	1924.	2034.	1888.	1961.
1869.	1968.	1977.	1968.	2005.	1913.	1814.	1840.	1841.	1867.
1956.	1883.	1845.	1816.	1920.	1911.	1885.	1860.	1741.	1853.
1882.	1813.	1782.	1706.	1745.	1794.	1713.	1779.	1817.	1729.
1855.	1783.	1717.	1744.	1776.	1671.	1769.	1679.	1680.	1810.
1826.	1819.	1681.	1699.	1656.	1787.	1729.	1684.	1679.	1759.
1699.	1754.	1647.	1727.	1796.	1691.	1790.	1690.	1819.	1822.
1787.	1820.	1782.	1700.	1704.	1598.	1762.	1668.	1637.	1637.
1700.	1967.	1890.	1857.	1652.	1750.	1683.	1688.	1650.	1636.
1610.	1877.	2192.	2338.	2003.	1871.	1816.	1698.	1773.	1771.
1650.	1647.	1635.	1727.	1727.	1612.	1804.	1670.	1655.	1534.
1743.	1750.	1769.	1874.	1866.	1909.	1835.	2135.	2246.	2417.
2750.	2645.	2679.	2572.	2479.	2410.	2268.	2306.	2153.	2072.
2053.	1922.	1891.	1859.	1799.	1856.	1804.	1670.	1655.	1534.
1600.	1614.	1706.	1582.	1680.	1601.	1617.	1674.	1651.	1567.
1652.	1548.	1596.	1515.	1525.	1577.	1582.	1574.	1642.	1646.
1643.	1648.	1540.	1697.	1554.	1683.	1555.	1519.	1631.	1598.
1531.	1604.	1558.	1493.	1556.	1563.	1605.	1632.	1520.	1543.
1534.	1511.	1533.	1570.	1481.	1463.	1567.	1522.	1494.	1753.
1847.	1759.	1656.	1561.	1553.	1536.	1519.	1537.	1563.	1600.
1648.	1744.	1609.	1567.	1555.	1554.	1643.	1636.	1615.	1633.
1654.	1710.	1581.	1619.	1643.	1687.	1722.	1735.	1710.	1647.
1745.	1757.	1738.	1812.	1829.	1789.	1868.	1810.	1810.	1850.
1845.	1958.	1998.	1893.	1922.	1943.	1990.	1982.	1936.	1961.
1957.	1972.	1928.	1946.	1956.	1890.	1810.	1612.	1678.	1556.
1369.	1302.	1137.	1068.	1014.	998.	933.	893.	824.	830.
789.	782.	819.	799.	812.	734.	746.	680.	720.	694.
606.	639.	603.	632.	602.	605.	613.	605.	589.	537.
515.	468.	454.	523.	507.	518.	503.	460.	474.	454.
419.	397.	427.	470.	374.	383.	327.	282.	320.	294.
313.	297.	243.	263.	239.	242.	255.	233.	263.	225.
216.	208.	207.	190.	224.	243.	218.	194.	214.	208.
195.	197.	203.	175.	198.	183.	216.	216.	172.	195.
154.	205.	203.	179.	162.	221.	184.	170.	193.	211.
187.	172.	181.	174.	176.	195.	172.	166.	199.	192.
164.	200.	198.	186.	184.	207.	193.	169.	170.	168.
203.	218.	178.	227.	196.	200.	224.	217.	214.	239.
266.	246.	327.	341.	524.	1737.	7557.	21759.	31301.	22583.
7597.	1195.	102.	-2.	13.	-5.	1.	8.	-5.	4.
CS137.6616	0.0	375.	137.	344.	368.	29.	0.0		





2755.	2460.	2843.	2925.	3012.	3091.	2971.	3055.	3155.
3124.	3201.	3255.	3294.	3302.	3203.	3452.	3432.	3502.
3559.	3469.	3511.	3619.	3546.	3775.	3710.	3860.	3821.
3774.	3877.	3876.	3710.	3719.	3573.	3071.	2546.	2296.
2030.	1894.	1875.	1780.	1737.	1638.	1611.	1594.	1522.
1409.	1503.	1385.	1362.	1302.	1291.	1216.	1231.	1166.
1154.	1060.	1035.	1030.	1014.	963.	901.	784.	805.
736.	690.	640.	626.	529.	534.	547.	463.	463.
394.	367.	366.	373.	310.	340.	295.	292.	252.
276.	319.	253.	247.	288.	249.	282.	264.	250.
286.	259.	278.	248.	271.	255.	236.	268.	230.
236.	304.	272.	294.	296.	301.	300.	368.	353.
414.	524.	855.	4929.	28064.	46336.	15927.	1052.	9.
-1.	-2.	9.	-2.	9.	8.	1.	4.	7.
11.	11.	-2.	9.	6.	6.	-1.	0.	3.
28651.114	510	385.	65.	26.	0.0	0.	0.	0.
0.	0.	-1.	0.	0.	0.	0.	1711.	1608.
1727.	1716.	1762.	1729.	1834.	1422.	1596.	1711.	1994.
1760.	1850.	1917.	1767.	1721.	1788.	1751.	1867.	1880.
1840.	1682.	1749.	1742.	1721.	1640.	1600.	1735.	1709.
1628.	1664.	1674.	1657.	1641.	1499.	1576.	1467.	1587.
1750.	1660.	1652.	1565.	1534.	1654.	1580.	1642.	1499.
1751.	1861.	2093.	2243.	2030.	1989.	1943.	1781.	1613.
1535.	1479.	1505.	1536.	1344.	1377.	1286.	1217.	1272.
1267.	1244.	1243.	1237.	1245.	1224.	1315.	1282.	1273.
1276.	1265.	1259.	1288.	1253.	1260.	1278.	1209.	1242.
1265.	1192.	1165.	1170.	1120.	1192.	1256.	1108.	1081.
1159.	1105.	1025.	967.	1054.	1038.	1013.	972.	999.
973.	978.	928.	920.	949.	911.	848.	963.	942.
921.	956.	892.	953.	931.	969.	831.	881.	906.
875.	922.	882.	884.	888.	923.	858.	900.	868.
903.	903.	915.	836.	873.	917.	900.	852.	851.
917.	859.	866.	863.	928.	1423.	3368.	2704.	886.
857.	935.	888.	899.	894.	838.	880.	854.	871.
858.	868.	950.	857.	914.	899.	858.	883.	880.
853.	871.	915.	877.	917.	944.	942.	922.	953.
918.	936.	850.	934.	915.	925.	884.	974.	901.
915.	953.	934.	975.	904.	927.	937.	948.	984.
933.	945.	996.	964.	972.	1050.	959.	1010.	1049.
996.	1021.	1015.	1051.	965.	1045.	1030.	1039.	1050.
1050.	997.	1019.	1044.	1077.	1057.	1038.	1091.	1129.
1106.	1146.	1134.	1150.	1152.	1113.	1180.	1168.	1193.
1178.	1200.	1237.	1236.	1276.	1295.	1373.	1298.	1293.
1330.	1406.	1352.	1437.	1352.	1404.	1399.	1533.	1472.
1550.	1511.	1534.	1578.	1533.	1667.	1596.	1679.	1694.
1753.	1776.	1904.	1877.	1909.	1863.	1929.	1858.	1837.
1795.	1794.	1562.	1400.	1122.	1018.	949.	809.	848.
864.	817.	783.	772.	743.	714.	693.	702.	643.
689.	622.	534.	555.	567.	509.	518.	497.	430.
396.	377.	353.	303.	312.	288.	228.	250.	197.
195.	180.	185.	162.	137.	129.	133.	105.	125.
110.	135.	110.	146.	127.	135.	99.	107.	106.
137.	125.	122.	128.	168.	129.	147.	122.	154.
186.	234.	474.	3530.	16691.	12643.	1014.	20.	3.
1.	4.	2.	3.	0.	-6.	-4.	1.	-1.
C0601.33	1.17	386.	60.	88.	25.	0.0	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
11993.	12270.	12376.	12661.	12673.	12863.	13056.	12836.	12577.
12483.	12466.	12228.	12179.	12069.	11940.	12069.	12172.	11710.
11373.	11515.	11329.	11048.	11007.	10884.	10603.	10675.	10430.
10145.	10259.	10048.	9999.	10227.	10329.	10202.	10815.	10862.
11741.	13724.	15301.	15307.	14343.	13292.	12225.	11399.	10606.
9775.	9404.	9056.	8710.	8126.	8554.	8375.	8066.	8469.
8213.	8375.	8259.	8215.	8026.	8068.	8022.	8146.	8404.

8993.	8223.	7799.	7863.	7761.	7607.	7458.	7449.	7411.	7351.
7318.	7353.	7270.	7253.	7126.	7019.	6982.	6936.	6991.	6979.
6888.	6976.	6814.	6699.	6664.	6826.	6627.	6546.	6641.	6644.
6857.	6683.	6613.	6652.	6549.	6567.	6583.	6585.	6546.	6412.
6562.	6592.	6456.	6496.	6560.	6416.	6343.	6528.	6463.	6452.
6466.	6464.	6551.	6478.	6472.	6508.	6301.	6516.	6564.	6498.
6467.	6330.	6355.	6546.	6422.	6462.	6378.	6556.	6487.	6493.
6279.	6375.	6506.	6499.	6412.	6374.	6488.	6590.	6595.	6543.
6473.	6513.	6473.	6386.	6500.	6536.	6621.	6675.	6658.	6524.
6660.	6713.	6724.	6835.	6844.	6648.	6872.	6858.	6949.	7065.
7137.	7045.	6959.	7002.	6971.	7056.	7107.	7159.	7141.	7038.
7293.	7142.	7141.	7146.	7283.	7262.	7187.	7400.	7444.	7578.
7464.	7601.	7644.	7611.	7552.	7807.	7620.	7687.	7833.	7857.
7768.	7955.	7815.	8006.	8078.	8169.	8290.	8503.	8565.	8349.
8384.	8589.	8621.	8492.	8774.	8780.	8877.	8873.	9000.	9233.
9174.	9240.	9240.	9406.	9721.	9672.	9914.	9883.	9882.	10117.
10174.	10560.	10286.	10645.	10680.	10807.	10967.	11012.	11224.	11460.
11343.	11607.	11730.	11965.	11914.	12010.	11767.	11512.	10809.	9828.
8821.	8439.	8308.	8068.	7835.	7858.	7708.	7868.	7875.	7736.
7803.	7708.	7447.	7612.	7571.	7615.	7504.	7484.	7280.	7422.
7394.	7508.	7303.	7275.	7074.	7039.	6966.	7057.	7107.	6900.
6979.	7129.	7287.	7173.	7235.	7242.	7178.	7399.	7232.	7353.
7181.	7324.	6857.	5962.	4954.	4378.	4067.	3926.	3778.	3634.
3618.	3536.	3430.	3393.	3462.	3391.	3507.	4720.	26371.	74800.
22532.	3078.	2168.	2001.	1951.	1820.	1698.	1517.	1482.	1363.
1228.	1045.	1043.	913.	890.	815.	743.	633.	611.	584.
506.	529.	503.	469.	462.	414.	446.	460.	435.	443.
466.	453.	508.	441.	441.	462.	479.	538.	506.	488.
607.	679.	994.	3429.	30675.	57738.	11347.	501.	83.	34.
38.	15.	30.	31.	14.	25.	30.	28.	26.	19.
12282.	615.	0.0.	380.	228.	230.	310.	2.0.0.	3020.	3000.
3180.	3160.	3140.	3120.	3100.	3080.	3060.	3040.	2850.	2835.
2990.	2975.	2955.	2920.	2900.	2885.	2865.	2845.	2690.	2675.
2820.	2795.	2780.	2760.	2750.	2735.	2720.	2700.	2545.	2530.
2660.	2640.	2625.	2615.	2600.	2590.	2575.	2560.	2410.	2400.
2520.	2500.	2490.	2480.	2460.	2445.	2440.	2425.	2285.	2280.
2390.	2380.	2360.	2350.	2340.	2320.	2315.	2300.	2175.	2160.
2265.	2255.	2240.	2235.	2220.	2205.	2195.	2180.	2080.	2075.
2150.	2140.	2135.	2120.	2115.	2100.	2095.	2085.	2005.	2000.
2060.	2055.	2045.	2040.	2035.	2025.	2020.	2015.	1945.	1940.
1995.	1985.	1980.	1975.	1965.	1960.	1955.	1950.	1890.	1885.
1935.	1930.	1925.	1920.	1915.	1905.	1900.	1895.	1845.	1840.
1880.	1875.	1875.	1870.	1865.	1860.	1855.	1850.	1805.	1800.
1840.	1835.	1830.	1825.	1820.	1820.	1815.	1810.	1971.	1950.
1759.	1659.	1798.	1757.	1805.	1841.	1780.	1715.	1827.	1794.
1741.	1829.	1856.	1917.	1766.	1744.	1688.	1720.	1810.	1815.
1759.	1740.	1735.	1768.	1851.	1768.	1800.	1805.	1852.	1776.
1746.	1850.	1759.	1789.	1778.	1859.	1781.	1807.	1932.	1916.
1459.	1843.	1851.	1827.	1816.	1748.	1881.	1853.	1844.	1751.
1457.	1876.	1874.	1831.	1793.	1854.	1890.	1910.	1858.	1887.
1775.	1809.	1788.	1897.	1836.	1933.	1803.	1829.	1698.	1668.
1917.	1845.	1883.	1922.	1760.	1818.	1793.	1719.	1717.	1834.
1729.	1725.	1713.	1848.	1752.	1729.	1730.	1703.	1772.	1705.
2056.	1823.	1681.	1721.	1685.	1650.	1642.	1705.	2091.	2068.
2285.	11880.	8075.	2089.	2111.	3253.	2960.	2068.	2057.	2076.
2047.	2023.	1972.	2100.	2063.	2080.	2077.	2011.	2198.	2143.
2061.	2027.	2059.	2018.	2029.	2112.	2077.	2174.	2137.	2288.
2136.	2146.	2207.	2163.	2115.	2226.	2261.	2210.	2325.	2469.
2239.	2259.	2261.	2236.	2351.	2288.	2413.	2288.	2251.	2176.
2404.	2201.	2260.	2214.	2167.	2176.	2157.	2202.	2276.	2230.
2139.	2161.	2214.	2169.	2283.	2204.	2231.	2256.	2436.	2423.
2397.	2369.	2380.	2377.	2611.	5481.	4222.	2529.	2698.	2737.
2544.	2596.	2430.	2602.	2610.	2576.	2645.	2656.	3056.	3086.
2757.	2925.	2852.	2627.	2952.	2898.	2974.	2939.	3750.	3704.
3225.	3123.	3308.	3233.	3431.	3423.	3572.	3676.		

3822.	3865.	4006.	3929.	2921.	3735.	2885.	2311.	2037.	1971.
1961.	1451.	1746.	1631.	1664.	1561.	1457.	1405.	1216.	1159.
983.	427.	640.	592.	515.	392.	361.	339.	297.	289.
324.	237.	278.	291.	284.	291.	331.	541.	2345.	18725.
8173.	45.	57.	31.	38.	33.	34.	27.	45.	19.
31.	19.	22.	19.	17.	16.	16.	9.	8.	12.
TH224	1.0	2.615	1.0	10.0	10.0	1.0	400.	0.0	
0	0	25	0	0	0	27	395		
32.0	10.0	1.0	1.0	0. 20 25 30					
1	3	5	7	9	10	15	20	25	30
00000	00000	00000	00000	00000	00000	00000	00000	00000	000110
00507	00460	012010	012709	012785	012294	011802	011155	010284	009699
009156	008323	007568	006905	006091	005632	005269	004923	004416	004165
003848	003631	003287	003075	002942	003708	002572	002170	002051	001968
001998	001885	001678	001649	001550	001428	001308	001252	001330	001167
001215	001315	001283	000982	000880	000897	000849	000818	000771	000765
000801	000717	000701	000673	000698	000638	000609	000563	000569	000578
000533	000561	000511	000485	000548	000625	000459	000499	000467	000457
000422	000460	000460	000428	000427	000640	000384	000411	000431	000670
000363	000358	000361	000325	000343	000349	000355	000356	000330	000335
000339	000324	000309	000331	000326	000280	000351	000287	000302	000278
000317	000299	000274	000268	000271	000255	000270	000237	000264	000243
000246	000213	000226	000254	000213	000254	000205	000199	000239	000202
000225	000210	000290	000263	000195	000221	000218	000205	000219	000199
000238	000326	000219	000195	000193	000187	000177	000189	000189	000227
000191	000191	000206	000199	000199	000191	000198	000188	000190	000190
000186	000179	000179	000231	000197	000223	000182	000201	000232	000193
000191	000210	000219	000193	000222	000232	000218	000218	000258	000234
000246	000178	000150	000140	000137	000134	000113	000113	000107	000112
000092	000098	000095	000110	000083	000075	000076	000068	000054	000060
000050	000058	000053	000064	000057	000055	000064	000051	000042	000046
000052	000082	000085	000392	000038	000033	000030	000036	000038	000025
000033	000025	000040	000028	000034	000023	000024	000023	000019	000024
000029	000079	000058	000023	000031	000026	000040	000043	000030	000026
000022	000018	000017	000027	000016	000028	000025	000016	000023	000020
000022	000023	000026	000019	000018	000023	000059	000031	000020	000025
000017	000016	000022	000023	000016	000025	000010	000023	000027	000020
000016	000021	000023	000028	000022	000021	000019	000020	000023	000025
000021	000023	000022	000017	000024	000010	000024	000016	000014	000014
000014	000015	000013	000019	000015	000013	000009	000020	000010	000025
000015	000013	000018	000016	000016	000026	000026	000014	000019	000013
000015	000023	000014	000019	000022	000018	000013	000017	000020	000025
000029	000017	000019	000020	000020	000013	000021	000017	000020	000015
000021	000017	000015	000018	000019	000021	000018	000017	000019	000021
000016	000023	000021	000023	000020	000022	000019	000009	000007	000010
000007	000012	000010	000006	000010	000017	000006	000006	000015	000004
000005	000008	000007	000004	000006	000001	000005	000003	000003	000003
000006	000001	000001	000000	000004	000001	000006	000006	000008	000096
000053	000000	000002	000001	000000	000000	000000	000000	000001	000002
000001	000002	000001	000002	000003	000003	000000	000001	000000	000000
IFIN									

APPENDIX IV

SAMPLE OUTPUT LISTING

BRIEF DESCRIPTION OF PHA RUNS  
TEST RUN WITH RESFUN GROUP

CONTROL NUMBERS

M(1) = 0 M(2) = 0 M(3) = 3 M(4) = 0 M(5) = 0 M(6) = 0  
M(7) = 7 M(8) = 0 M(9) = 9 M(10) = 0 M(11) = 0 M(12) = 0  
M(13) = 0 M(14) = 2 M(15) = 0 M(16) = 16 M(17) = 17 M(18) = 0  
M(19) = 0 M(20) = 0 M(21) = 0 M(22) = 0 M(23) = 0 M(24) = 0

EM = 14.51906 CHANNELS/MEV

ELIMIT = 2.75500

ITERATIVE ERROR TOLERANCE, EPS = 0.00001

NUMBER OF BETA SOURCE SETS, OJ50 = 1 NM = 1

MAX NUMBER OF ITERATIONS, ITMAX = 51

NUMBER OF CHANNELS INPUT, N = 40

GE(LI) CRYSTAL SIZE = 3.26 X 3.10 (CM)

A

STANDARD SOURCE SPECTRAL PARAMETERS

8 SPECTRA IN STANDARD SOURCE DECK

CHANNELS ONE TO 2 ASSUMED AS REDUNDANT

REFERENCE COARSE GAIN = 0.0

STANDARD SOURCE	PHOTOPEAK		X-RAY OR .5 PEAK		SHIFT		PHOTOPEAK	
	FROM	TO	FROM	TO	CHANNELS	SPECTRUM	ENERGIES	MEV
CE139	358	0	0	0	0.0	0.0	0.16600	0.0
HG203	391	0	0	0	0.0	0.0	0.27900	0.0
SR85	389	0	90	108	0.0	0.0	0.51400	0.0
CS137	375	0	344	368	0.0	0.0	0.66160	0.0
MN54	376	0	0	0	0.0	0.0	0.83500	0.0
ZN65	385	0	0	0	0.0	0.0	1.11400	0.51900
CO60	386	0	88	94	0.0	0.0	1.33000	1.17000
TH228	390	0	230	310	0.0	0.0	2.61500	0.0

B

**CE 139 SOURCE**[illegible]

HG203 SOURCE.

[illegible]

## STANDARD SOURCE SPECTRA

## SR85 SOURCE

1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.
1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.	1913.
1913.	1913.	1913.	1913.	1913.	1913.	1924.	2034.	1888.	1961.
1956.	1883.	1845.	1816.	1920.	1911.	1814.	1840.	1841.	1867.
1882.	1813.	1782.	1706.	1745.	1794.	1885.	1860.	1741.	1853.
1855.	1783.	1717.	1794.	1776.	1671.	1713.	1779.	1817.	1729.
1826.	1819.	1681.	1699.	1656.	1787.	1769.	1679.	1680.	1810.
1699.	1754.	1647.	1727.	1796.	1691.	1729.	1684.	1679.	1759.
1787.	1820.	1782.	1700.	1704.	1598.	1790.	1590.	1819.	1822.
1815.	1807.	1800.	1792.	1785.	1777.	1770.	1762.	1755.	1748.
1740.	1713.	1725.	1718.	1710.	1703.	1695.	1688.	1650.	1636.
1650.	1647.	1635.	1727.	1727.	1612.	1816.	1698.	1773.	1771.
1743.	1750.	1769.	1474.	1966.	1909.	1983.	2135.	2246.	2417.
2750.	2645.	2679.	2572.	2479.	2410.	2268.	2306.	2153.	2072.
2053.	1922.	1891.	1859.	1799.	1856.	1804.	1670.	1655.	1534.
1640.	1614.	1706.	1592.	1680.	1601.	1617.	1674.	1651.	1567.
1652.	1548.	1556.	1515.	1525.	1577.	1582.	1574.	1642.	1646.
1643.	1648.	1540.	1657.	1554.	1683.	1555.	1519.	1631.	1598.
1531.	1604.	1558.	1493.	1556.	1563.	1605.	1632.	1520.	1543.
1534.	1511.	1533.	1570.	1481.	1463.	1547.	1522.	1494.	1753.
1447.	1759.	1656.	1561.	1553.	1536.	1519.	1537.	1563.	1600.
1648.	1744.	1609.	1567.	1555.	1554.	1643.	1636.	1615.	1633.
1654.	1710.	1581.	1619.	1643.	1687.	1722.	1735.	1710.	1647.
1745.	1757.	1738.	1812.	1829.	1799.	1868.	1810.	1810.	1850.
1845.	1958.	1988.	1893.	1922.	1943.	1990.	1982.	1936.	1961.
1957.	1972.	1928.	1996.	1956.	1890.	1810.	1812.	1678.	1556.
1309.	1302.	1137.	1068.	1014.	998.	933.	893.	824.	630.
789.	782.	819.	799.	812.	734.	746.	680.	720.	694.
606.	639.	603.	632.	602.	605.	613.	605.	589.	537.
515.	468.	454.	523.	507.	518.	503.	460.	474.	454.
419.	397.	427.	470.	374.	383.	327.	282.	320.	294.
313.	257.	243.	263.	239.	242.	255.	233.	263.	225.
216.	278.	207.	190.	224.	243.	218.	194.	214.	208.
195.	197.	208.	175.	198.	183.	216.	216.	172.	195.
154.	205.	203.	179.	162.	221.	184.	170.	193.	211.
187.	172.	181.	174.	176.	195.	172.	166.	199.	192.
164.	200.	198.	186.	184.	207.	193.	169.	170.	168.
203.	218.	178.	227.	196.	200.	224.	217.	214.	239.
256.	206.	327.	341.	524.	1737.	7557.	21759.	31361.	22583.
7597.	1195.	102.	-2.	13.	-5.	1.	8.	-5.	1.

## STANDARD SOURCE SPECTRA

## CS137 SOURCE

6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.
6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.
6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6150.	6271.
6070.	6035.	6113.	5882.	5965.	5911.	5911.	5919.	5886.	5946.
5893.	5932.	5924.	5969.	5734.	5688.	5493.	5706.	5787.	5862.
5689.	5479.	5400.	5496.	5529.	5635.	5512.	5506.	5434.	5498.
5122.	5575.	5776.	5606.	5631.	5635.	5524.	5476.	5466.	5532.
5553.	5396.	5423.	5478.	5369.	5364.	5431.	5411.	5328.	5347.
4482.	5479.	5336.	5247.	5275.	5192.	5141.	5203.	5181.	5148.
5312.	5228.	5175.	5143.	5208.	5269.	5252.	5456.	5509.	5514.
4792.	5921.	6056.	6746.	7453.	7946.	8292.	7892.	7665.	7434.
6950.	6538.	6364.	5996.	4997.	5561.	5412.	5329.	5232.	5042.
5092.	4982.	4898.	4815.	4764.	4762.	4601.	4552.	4749.	4682.
4643.	4603.	4774.	4719.	4680.	4725.	4741.	4748.	4653.	4643.
3946.	4679.	4714.	4779.	4598.	4666.	4573.	4654.	4438.	4493.
4517.	4538.	4427.	4458.	4424.	4416.	4266.	4421.	4469.	4383.
3938.	4280.	4265.	4292.	4249.	4092.	4299.	4089.	4108.	4126.
4164.	4168.	4091.	4177.	4032.	4055.	4159.	4244.	4129.	4210.
4059.	4088.	4075.	4139.	4035.	3968.	4010.	4188.	4039.	4133.
4154.	4165.	4176.	4115.	4150.	4121.	4150.	4169.	4189.	4254.
4102.	4297.	4371.	4265.	4203.	4252.	4094.	4293.	4189.	4414.
4332.	4326.	4450.	4426.	4402.	4508.	4529.	4526.	4573.	4623.
4642.	4413.	4592.	4694.	4781.	4818.	4884.	4860.	4877.	4994.
4998.	4977.	5057.	5081.	5081.	5255.	5226.	5201.	5369.	5341.
5436.	5490.	5411.	5571.	5650.	5695.	5585.	5728.	5744.	5751.
5992.	5972.	5939.	6053.	6129.	6336.	6021.	6182.	6355.	6347.
6467.	6411.	6457.	6428.	6285.	6209.	6163.	5989.	5618.	5337.
4518.	4138.	3618.	3438.	3225.	3042.	3046.	2890.	2770.	2788.
2280.	2566.	2614.	2462.	2305.	2323.	2284.	2256.	2233.	2198.
2037.	1907.	2052.	1957.	1853.	1938.	1811.	1761.	1628.	1696.
1574.	1584.	1515.	1367.	1385.	1354.	1309.	1315.	1148.	1123.
1025.	977.	936.	925.	876.	841.	847.	787.	746.	772.
706.	689.	738.	658.	655.	665.	567.	573.	598.	516.
551.	591.	542.	524.	523.	533.	552.	523.	484.	529.
483.	503.	574.	548.	545.	543.	543.	537.	534.	537.
529.	526.	524.	521.	518.	516.	513.	510.	507.	505.
502.	499.	467.	454.	491.	488.	486.	483.	486.	508.
1224.	3945.	23224.	72927.	75662.	28766.	3302.	167.	19.	30.
43.	16.	20.	19.	17.	18.	14.	20.	20.	15.
10.	18.	12.	18.	10.	5.	13.	27.	29.	1.



## STANDARD SOURCE SPECTRA

## MNS4 SOURCE

3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.
3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.
3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.	3438.
3405.	3424.	3370.	3388.	3390.	3530.	3592.	3634.	3433.	3391.
3317.	3328.	3378.	3434.	3277.	3230.	3145.	3221.	3295.	3254.
3278.	3268.	3322.	3093.	3317.	3254.	3095.	3221.	3140.	3673.
3179.	3212.	3194.	3074.	3086.	3000.	2953.	3083.	3066.	2947.
2917.	3068.	2933.	2873.	2951.	2967.	2903.	2981.	2951.	2857.
2903.	2990.	3130.	3006.	3109.	3253.	3351.	3783.	4315.	4658.
4533.	4231.	4102.	3861.	3662.	3578.	3475.	3158.	3193.	2974.
2768.	2842.	2611.	2665.	2612.	2557.	2618.	2441.	2442.	2510.
2541.	2494.	2432.	2507.	2516.	2629.	2533.	2401.	2486.	2501.
2515.	2591.	2525.	2519.	2565.	2510.	2457.	2506.	2487.	2362.
2317.	2356.	2331.	2401.	2414.	2338.	2376.	2228.	2305.	2305.
2169.	2283.	2274.	2342.	2278.	2272.	2194.	2125.	2212.	2211.
2161.	2234.	2116.	2208.	2043.	2204.	2173.	2114.	2007.	2129.
2249.	2237.	2152.	2192.	2085.	2078.	2043.	2076.	2111.	2131.
2250.	2215.	2021.	2162.	2164.	2110.	2194.	2073.	2116.	2221.
2152.	2060.	2155.	2203.	2122.	2151.	2190.	2149.	2154.	2171.
2202.	2209.	2146.	2111.	2185.	1953.	2129.	2105.	2117.	2142.
2133.	2235.	2240.	2254.	2195.	2190.	2219.	2224.	2261.	2320.
2241.	2257.	2299.	2313.	2233.	2322.	2224.	2307.	2295.	2264.
2258.	2357.	2379.	2366.	2320.	2310.	2311.	2341.	2428.	2453.
2374.	2475.	2474.	2403.	2553.	2534.	2497.	2625.	2493.	2550.
2537.	2639.	2665.	2660.	2454.	2639.	2774.	2722.	2741.	2828.
2755.	2960.	2893.	2925.	2994.	3012.	3091.	2971.	3055.	3155.
3124.	3271.	3255.	3294.	3393.	3332.	3203.	3452.	3432.	3502.
3559.	3469.	3511.	3619.	3546.	3775.	3674.	3710.	3869.	3821.
3774.	3877.	3876.	3710.	3719.	3573.	3397.	3071.	2546.	2296.
2530.	1894.	1875.	1780.	1737.	1638.	1611.	1594.	1514.	1522.
1409.	1503.	1385.	1362.	1302.	1291.	1216.	1231.	1185.	1166.
1154.	1060.	1035.	1030.	1014.	963.	901.	913.	784.	805.
736.	699.	649.	626.	529.	554.	554.	547.	463.	463.
394.	367.	366.	373.	310.	340.	304.	295.	292.	252.
276.	319.	253.	297.	284.	249.	242.	240.	264.	250.
286.	256.	278.	244.	271.	255.	235.	268.	230.	255.
236.	304.	272.	294.	296.	301.	300.	368.	353.	342.
414.	524.	855.	4929.	28054.	46336.	15927.	1052.	20.	9.
-1.	-2.	9.	-2.	9.	8.	1.	8.	4.	7.
11.	1.	-2.	9.	5.	8.	6.	-1.	0.	1.

## STANDARD SOURCE SPECTRA

## ZM65 SOURCE

1751.	1751.	1751.	1751.	1751.	1751.	1751.	1751.	1751.	1751.
1751.	1751.	1751.	1751.	1751.	1751.	1751.	1751.	1751.	1751.
1751.	1751.	1751.	1751.	1751.	1751.	1779.	1913.	1867.	1904.
1730.	1850.	1917.	1787.	1721.	1788.	1751.	1730.	1745.	1840.
1840.	1682.	1749.	1742.	1721.	1645.	1600.	1735.	1583.	1729.
1628.	1664.	1674.	1657.	1641.	1459.	1574.	1467.	1636.	1527.
1750.	1660.	1652.	1555.	1534.	1554.	1580.	1551.	1642.	1440.
1751.	1961.	2093.	2243.	2030.	1989.	1943.	1781.	1705.	1613.
1535.	1479.	1505.	1536.	1344.	1377.	1286.	1217.	1312.	1272.
1267.	1244.	1243.	1237.	1245.	1224.	1315.	1282.	1273.	1314.
1276.	1265.	1259.	1288.	1253.	1260.	1275.	1209.	1242.	1182.
1265.	1192.	1165.	1170.	1170.	1192.	1254.	1160.	1108.	1051.
1159.	1106.	1025.	967.	1054.	1038.	1011.	912.	972.	900.
973.	978.	928.	920.	843.	911.	931.	848.	963.	842.
921.	956.	852.	953.	931.	909.	831.	881.	892.	900.
875.	922.	882.	884.	888.	923.	858.	900.	850.	868.
903.	903.	915.	836.	873.	917.	900.	852.	857.	851.
917.	859.	866.	863.	828.	1423.	3368.	2704.	1065.	846.
857.	935.	888.	899.	894.	838.	840.	908.	454.	471.
858.	864.	950.	857.	914.	850.	858.	836.	883.	980.
853.	871.	915.	877.	917.	944.	942.	845.	922.	953.
918.	936.	850.	934.	915.	925.	884.	974.	946.	901.
915.	953.	934.	975.	904.	927.	937.	944.	969.	984.
933.	945.	956.	964.	972.	1050.	959.	1710.	992.	1049.
906.	1021.	1015.	1051.	965.	1045.	1030.	1031.	1030.	1050.
1050.	997.	1019.	1044.	1077.	1057.	1039.	1135.	1091.	1129.
1106.	1146.	1134.	1152.	1113.	1110.	1180.	1168.	1193.	1227.
1178.	1207.	1237.	1236.	1276.	1295.	1373.	1298.	1293.	1341.
1330.	1400.	1322.	1437.	1352.	1404.	1399.	1533.	1469.	1472.
1550.	1511.	1514.	1578.	1533.	1667.	1596.	1679.	1718.	1694.
1753.	1776.	1974.	1897.	1909.	1863.	1929.	1858.	1800.	1837.
1755.	1794.	1542.	1405.	1122.	1018.	949.	809.	879.	848.
864.	817.	723.	772.	743.	714.	691.	702.	638.	643.
689.	622.	534.	555.	567.	509.	518.	407.	432.	436.
396.	377.	353.	373.	312.	288.	228.	250.	224.	197.
195.	140.	165.	162.	137.	129.	133.	136.	105.	125.
110.	135.	110.	126.	127.	135.	99.	107.	119.	100.
137.	135.	122.	128.	168.	129.	147.	122.	154.	160.
186.	234.	474.	3579.	10651.	12043.	1114.	20.	2.	3.
1.	4.	2.	3.	0.	-6.	-4.	1.	7.	1.

## STANDARD SOURCE SPECTRA

## CO60 SOURCE

12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.
12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.
12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.	12673.
12483.	12466.	12228.	12179.	12069.	11990.	12069.	12172.	11710.	11621.
11320.	11515.	11329.	11048.	11007.	10858.	10603.	10675.	10430.	10491.
10195.	10259.	10048.	9999.	10227.	10329.	10202.	10675.	10811.	10862.
11741.	11724.	15301.	15307.	14343.	13292.	12225.	11359.	10696.	10608.
8775.	8494.	9056.	8770.	8726.	8554.	8375.	8066.	8469.	8236.
8213.	8375.	8259.	8215.	8026.	8058.	8022.	8146.	8099.	8052.
9025.	7957.	7910.	7863.	7761.	7607.	7458.	7449.	7411.	7351.
7318.	7353.	7270.	7253.	7126.	7019.	6982.	6936.	6991.	6979.
6888.	6976.	6814.	6699.	6664.	6826.	6627.	6546.	6641.	6644.
6237.	6683.	6613.	6652.	6549.	6567.	6583.	6585.	6546.	6412.
6502.	6592.	6456.	6456.	6560.	6416.	6343.	6528.	6463.	6452.
4466.	6464.	5551.	6478.	6472.	6508.	6301.	6516.	6564.	6498.
6467.	6337.	6155.	6546.	6422.	6462.	6378.	6556.	6487.	6493.
6279.	6575.	6506.	6499.	6412.	6374.	6488.	6590.	6595.	6543.
6473.	6513.	6473.	6386.	6500.	6530.	6621.	6675.	6658.	6524.
6586.	6462.	6610.	6758.	6638.	6644.	6608.	6742.	6718.	6639.
6660.	6713.	6724.	6835.	6844.	6848.	6872.	6858.	6949.	7065.
7137.	7045.	6959.	7002.	6971.	7056.	7107.	7159.	7141.	7038.
7293.	7142.	7141.	7146.	7283.	7252.	7187.	7400.	7444.	7578.
7404.	7601.	7644.	7611.	7552.	7807.	7620.	7687.	7833.	7857.
7768.	7955.	7815.	8006.	8078.	8169.	8291.	8503.	8565.	8349.
8384.	8589.	8621.	8492.	8774.	8790.	8877.	8873.	9030.	9213.
9174.	9240.	9240.	9406.	9721.	9672.	9914.	9893.	9882.	13117.
10174.	10560.	10266.	10645.	10680.	10807.	10967.	11012.	11224.	11460.
11343.	11607.	11730.	11965.	11914.	12010.	11767.	11512.	10809.	9828.
8821.	8439.	8308.	8068.	7935.	7858.	7708.	7868.	7875.	7736.
7813.	7708.	7447.	7812.	7571.	7615.	7504.	7484.	7280.	7422.
7394.	7508.	7303.	7275.	7074.	7039.	6966.	7057.	7107.	6900.
6979.	7129.	7267.	7173.	7235.	7242.	7170.	7399.	7232.	7353.
7181.	7324.	6857.	5982.	4954.	4378.	4067.	3926.	3778.	3634.
3618.	3936.	3420.	3393.	3462.	3391.	3597.	4720.	26371.	74800.
22532.	3078.	2678.	2001.	1951.	1820.	1698.	1517.	1482.	1363.
1278.	1045.	1043.	913.	890.	815.	743.	633.	611.	584.
596.	529.	503.	469.	462.	414.	446.	460.	435.	443.
466.	453.	528.	441.	441.	462.	479.	538.	506.	488.
677.	679.	954.	3429.	30675.	57738.	11347.	561.	83.	34.
38.	15.	30.	31.	14.	25.	30.	28.	26.	1.

## STANDARD SOURCE SPECTRA

## TH228 SOURCE

3160.	3160.	3140.	3120.	3100.	3080.	3067.	3040.	3020.	3000.
2995.	2975.	2955.	2949.	2923.	2900.	2885.	2865.	2850.	2835.
2870.	2795.	2780.	2760.	2750.	2735.	2720.	2700.	2690.	2675.
2660.	2640.	2625.	2615.	2600.	2590.	2575.	2560.	2545.	2530.
2520.	2500.	2490.	2480.	2460.	2445.	2440.	2425.	2410.	2400.
2390.	2380.	2360.	2350.	2340.	2320.	2315.	2300.	2285.	2280.
2265.	2255.	2240.	2235.	2220.	2205.	2195.	2180.	2175.	2160.
2150.	2140.	2135.	2120.	2115.	2100.	2095.	2085.	2080.	2075.
2060.	2055.	2045.	2040.	2035.	2025.	2020.	2015.	2005.	2000.
1995.	1985.	1980.	1975.	1965.	1960.	1955.	1950.	1945.	1940.
1935.	1930.	1925.	1915.	1910.	1905.	1895.	1890.	1885.	1880.
1860.	1875.	1875.	1870.	1865.	1860.	1855.	1850.	1845.	1840.
1840.	1835.	1830.	1825.	1820.	1815.	1810.	1805.	1800.	1800.
1790.	1659.	1758.	1757.	1805.	1841.	1785.	1715.	1971.	1950.
1741.	1829.	1856.	1917.	1766.	1744.	1680.	1720.	1827.	1794.
1759.	1740.	1735.	1788.	1851.	1768.	1800.	1805.	1810.	1815.
1786.	1850.	1789.	1789.	1778.	1859.	1781.	1827.	1852.	1776.
1859.	1843.	1851.	1827.	1916.	1740.	1881.	1853.	1932.	1916.
1457.	1876.	1878.	1831.	1793.	1859.	1890.	1910.	1844.	1751.
1775.	1859.	1788.	1897.	1836.	1933.	1803.	1829.	1858.	1847.
1917.	1985.	1883.	1922.	1760.	1818.	1793.	1719.	1694.	1668.
1729.	1725.	2113.	1948.	1752.	1729.	1730.	1703.	1717.	1834.
2056.	1823.	1681.	1721.	1655.	1650.	1642.	1705.	1772.	1705.
1714.	1723.	1732.	1741.	1750.	1759.	1765.	1777.	1786.	1795.
1804.	1813.	1922.	1831.	1840.	1849.	1858.	1867.	1876.	1885.
1493.	1902.	1911.	1920.	1929.	1938.	1947.	1956.	1965.	1974.
1993.	1992.	2001.	2010.	2019.	2028.	2037.	2046.	2055.	2064.
2073.	2082.	2091.	2100.	2109.	2118.	2127.	2136.	2145.	2154.
2163.	2172.	2181.	2190.	2199.	2208.	2217.	2226.	2235.	2244.
2252.	2261.	2270.	2279.	2288.	2297.	2306.	2315.	2324.	2333.
2342.	2351.	2360.	2369.	2378.	2387.	2396.	2405.	2414.	2423.
2549.	2596.	2430.	2602.	2610.	2576.	2549.	2656.	2698.	2737.
2757.	2925.	2852.	2827.	2952.	2838.	2979.	2939.	3056.	3086.
3225.	3123.	3178.	3233.	3431.	3421.	3572.	3676.	3750.	3704.
3322.	3865.	4066.	3929.	2921.	3715.	2885.	2311.	2037.	1971.
1961.	1851.	1746.	1631.	1564.	1581.	1457.	1405.	1216.	1159.
983.	827.	682.	592.	515.	392.	361.	339.	297.	280.
324.	237.	278.	291.	284.	291.	331.	541.	2345.	18725.
8173.	85.	57.	31.	36.	33.	34.	27.	45.	19.
31.	19.	22.	19.	17.	16.	15.	9.	8.	1.

# RESULTS OF PHOTOPEAK FITTING

INDEX	STANDARD SOURCE	PULSE-HEIGHT (CHANNELS)	STANDARD DEVIATION (CHANNELS)	AREA (COUNTS/TIME)
1	CE139	0.3584167E 03	0.3066857E 01	0.3102433E 06
2	HG203	0.3806990E 03	0.1923298E 01	0.3694376E 05
3	SR85	0.3895884E 03	0.1094684E 01	0.8907631E 05
4	CS137	0.3750823E 03	0.9007936E 00	0.2089790E 06
5	MN54	0.3753264E 03	0.7370086E 00	0.9434959E 05
6	ZN65	0.3858713E 03	0.6066732E 00	0.3282250E 05
7	CO60	0.3862827E 03	0.6031659E 00	0.1016444E 06
8	TH228	0.3807041E 03	0.4792651E 00	0.2873323E 05

(D)

# RESULTS OF PHOTOPEAK FITTING

INDEX	STANDARD SOURCE	PULSE-HEIGHT (CHANNELS)	STANDARD DEVIATION (CHANNELS)	AREA (COUNTS/TIME)
1	CE139	0.0	0.0	0.0
2	HG203	0.0	0.0	0.0
3	SR85	0.0	0.0	0.0
4	CS137	0.0	0.0	0.0
5	MN54	0.0	0.0	0.0
6	ZN65	0.1778325E 03	0.6738757E 00	0.5125484E 04
7	CO60	0.3404636E 03	0.5818627E 00	0.1171379E 06
8	TH228	0.0	0.0	0.0

(D)

0.1660 MEV

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INTEGRAL      =  C.7511505E 00
PHOTOFRACTION =  C.5719532E 00

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## 0.2790 MEV

INTEGRAL = 0.2129635E 01  
PHOTOFRACTION = 0.3196281E 00

# NORMALIZED CONTINUUM OF STANDARD SPECTRA

SR85 SOURCE	ENERGY	Q.5140 MEV
0.3889347E-01	0.3885337E-01	0.3861327E-01
0.3860297E-01	0.3855267E-01	0.3841278E-01
0.3840247E-01	0.3845230E-01	0.3821228E-01
0.3820198E-01	0.3825180E-01	0.3801178E-01
0.3800148E-01	0.3805130E-01	0.3781128E-01
0.3780099E-01	0.3785080E-01	0.3761078E-01
0.3760049E-01	0.3765030E-01	0.3741028E-01
0.3740000E-01	0.3744980E-01	0.3720978E-01
0.3720000E-01	0.3724930E-01	0.3700928E-01
0.3700000E-01	0.3704880E-01	0.3680878E-01
0.3680000E-01	0.3684830E-01	0.3660828E-01
0.3660000E-01	0.3664780E-01	0.3640778E-01
0.3640000E-01	0.3644730E-01	0.3620728E-01
0.3620000E-01	0.3624680E-01	0.3600678E-01
0.3600000E-01	0.3604630E-01	0.3580628E-01
0.3580000E-01	0.3584580E-01	0.3560578E-01
0.3560000E-01	0.3564530E-01	0.3540528E-01
0.3540000E-01	0.3544480E-01	0.3520478E-01
0.3520000E-01	0.3524430E-01	0.3500428E-01
0.3500000E-01	0.3504380E-01	0.3480378E-01
0.3480000E-01	0.3484330E-01	0.3460328E-01
0.3460000E-01	0.3464280E-01	0.3440278E-01
0.3440000E-01	0.3444230E-01	0.3420228E-01
0.3420000E-01	0.3424180E-01	0.3400178E-01
0.3400000E-01	0.3404130E-01	0.3380128E-01
0.3380000E-01	0.3384080E-01	0.3360078E-01
0.3360000E-01	0.3364030E-01	0.3340028E-01
0.3340000E-01	0.3343980E-01	0.3320000E-01
0.3320000E-01	0.3323930E-01	0.3300000E-01
0.3300000E-01	0.3303880E-01	0.3280000E-01
0.3280000E-01	0.3283830E-01	0.3260000E-01
0.3260000E-01	0.3263780E-01	0.3240000E-01
0.3240000E-01	0.3243730E-01	0.3220000E-01
0.3220000E-01	0.3223680E-01	0.3200000E-01
0.3200000E-01	0.3203630E-01	0.3180000E-01
0.3180000E-01	0.3183580E-01	0.3160000E-01
0.3160000E-01	0.3163530E-01	0.3140000E-01
0.3140000E-01	0.3143480E-01	0.3120000E-01
0.3120000E-01	0.3123430E-01	0.3100000E-01
0.3100000E-01	0.3103380E-01	0.3080000E-01
0.3080000E-01	0.3083330E-01	0.3060000E-01
0.3060000E-01	0.3063280E-01	0.3040000E-01
0.3040000E-01	0.3043230E-01	0.3020000E-01
0.3020000E-01	0.3023180E-01	0.3000000E-01
0.3000000E-01	0.3003130E-01	0.2980000E-01
0.2980000E-01	0.2983080E-01	0.2960000E-01
0.2960000E-01	0.2963030E-01	0.2940000E-01
0.2940000E-01	0.2942980E-01	0.2920000E-01
0.2920000E-01	0.2922930E-01	0.2900000E-01
0.2900000E-01	0.2902880E-01	0.2880000E-01
0.2880000E-01	0.2882830E-01	0.2860000E-01
0.2860000E-01	0.2862780E-01	0.2840000E-01
0.2840000E-01	0.2842730E-01	0.2820000E-01
0.2820000E-01	0.2822680E-01	0.2800000E-01
0.2800000E-01	0.2802630E-01	0.2780000E-01
0.2780000E-01	0.2782580E-01	0.2760000E-01
0.2760000E-01	0.2762530E-01	0.2740000E-01
0.2740000E-01	0.2742480E-01	0.2720000E-01
0.2720000E-01	0.2722430E-01	0.2700000E-01
0.2700000E-01	0.2702380E-01	0.2680000E-01
0.2680000E-01	0.2682330E-01	0.2660000E-01
0.2660000E-01	0.2662280E-01	0.2640000E-01
0.2640000E-01	0.2642230E-01	0.2620000E-01
0.2620000E-01	0.2622180E-01	0.2600000E-01
0.2600000E-01	0.2602130E-01	0.2580000E-01
0.2580000E-01	0.2582080E-01	0.2560000E-01
0.2560000E-01	0.2562030E-01	0.2540000E-01
0.2540000E-01	0.2541980E-01	0.2520000E-01
0.2520000E-01	0.2521930E-01	0.2500000E-01
0.2500000E-01	0.2501880E-01	0.2480000E-01
0.2480000E-01	0.2481830E-01	0.2460000E-01
0.2460000E-01	0.2461780E-01	0.2440000E-01
0.2440000E-01	0.2441730E-01	0.2420000E-01
0.2420000E-01	0.2421680E-01	0.2400000E-01
0.2400000E-01	0.2401630E-01	0.2380000E-01
0.2380000E-01	0.2381580E-01	0.2360000E-01
0.2360000E-01	0.2361530E-01	0.2340000E-01
0.2340000E-01	0.2341480E-01	0.2320000E-01
0.2320000E-01	0.2321430E-01	0.2300000E-01
0.2300000E-01	0.2301380E-01	0.2280000E-01
0.2280000E-01	0.2281330E-01	0.2260000E-01
0.2260000E-01	0.2261280E-01	0.2240000E-01
0.2240000E-01	0.2241230E-01	0.2220000E-01
0.2220000E-01	0.2221180E-01	0.2200000E-01
0.2200000E-01	0.2201130E-01	0.2180000E-01
0.2180000E-01	0.2181080E-01	0.2160000E-01
0.2160000E-01	0.2161030E-01	0.2140000E-01
0.2140000E-01	0.2140980E-01	0.2120000E-01
0.2120000E-01	0.2120930E-01	0.2100000E-01
0.2100000E-01	0.2100880E-01	0.2080000E-01
0.2080000E-01	0.2080830E-01	0.2060000E-01
0.2060000E-01	0.2060780E-01	0.2040000E-01
0.2040000E-01	0.2040730E-01	0.2020000E-01
0.2020000E-01	0.2020680E-01	0.2000000E-01
0.2000000E-01	0.2000630E-01	0.1980000E-01
0.1980000E-01	0.1980580E-01	0.1960000E-01
0.1960000E-01	0.1960530E-01	0.1940000E-01
0.1940000E-01	0.1940480E-01	0.1920000E-01
0.1920000E-01	0.1920430E-01	0.1900000E-01
0.1900000E-01	0.1900380E-01	0.1880000E-01
0.1880000E-01	0.1880330E-01	0.1860000E-01
0.1860000E-01	0.1860280E-01	0.1840000E-01
0.1840000E-01	0.1840230E-01	0.1820000E-01
0.1820000E-01	0.1820180E-01	0.1800000E-01
0.1800000E-01	0.1800130E-01	0.1780000E-01
0.1780000E-01	0.1780080E-01	0.1760000E-01
0.1760000E-01	0.1760030E-01	0.1740000E-01
0.1740000E-01	0.1740000E-01	0.1720000E-01
0.1720000E-01	0.1720000E-01	0.1700000E-01
0.1700000E-01	0.1700000E-01	0.1680000E-01
0.1680000E-01	0.1680000E-01	0.1660000E-01
0.1660000E-01	0.1660000E-01	0.1640000E-01
0.1640000E-01	0.1640000E-01	0.1620000E-01
0.1620000E-01	0.1620000E-01	0.1600000E-01
0.1600000E-01	0.1600000E-01	0.1580000E-01
0.1580000E-01	0.1580000E-01	0.1560000E-01
0.1560000E-01	0.1560000E-01	0.1540000E-01
0.1540000E-01	0.1540000E-01	0.1520000E-01
0.1520000E-01	0.1520000E-01	0.1500000E-01
0.1500000E-01	0.1500000E-01	0.1480000E-01
0.1480000E-01	0.1480000E-01	0.1460000E-01
0.1460000E-01	0.1460000E-01	0.1440000E-01
0.1440000E-01	0.1440000E-01	0.1420000E-01
0.1420000E-01	0.1420000E-01	0.1400000E-01
0.1400000E-01	0.1400000E-01	0.1380000E-01
0.1380000E-01	0.1380000E-01	0.1360000E-01
0.1360000E-01	0.1360000E-01	0.1340000E-01
0.1340000E-01	0.1340000E-01	0.1320000E-01
0.1320000E-01	0.1320000E-01	0.1300000E-01
0.1300000E-01	0.1300000E-01	0.1280000E-01
0.1280000E-01	0.1280000E-01	0.1260000E-01
0.1260000E-01	0.1260000E-01	0.1240000E-01
0.1240000E-01	0.1240000E-01	0.1220000E-01
0.1220000E-01	0.1220000E-01	0.1200000E-01
0.1200000E-01	0.1200000E-01	0.1180000E-01
0.1180000E-01	0.1180000E-01	0.1160000E-01
0.1160000E-01	0.1160000E-01	0.1140000E-01
0.1140000E-01	0.1140000E-01	0.1120000E-01
0.1120000E-01	0.1120000E-01	0.1100000E-01
0.1100000E-01	0.1100000E-01	0.1080000E-01
0.1080000E-01	0.1080000E-01	0.1060000E-01
0.1060000E-01	0.1060000E-01	0.1040000E-01
0.1040000E-01	0.1040000E-01	0.1020000E-01
0.1020000E-01	0.1020000E-01	0.1000000E-01
0.1000000E-01	0.1000000E-01	0.0980000E-01
0.0980000E-01	0.0980000E-01	0.0960000E-01
0.0960000E-01	0.0960000E-01	0.0940000E-01
0.0940000E-01	0.0940000E-01	0.0920000E-01
0.0920000E-01	0.0920000E-01	0.0900000E-01
0.0900000E-01	0.0900000E-01	0.0880000E-01
0.0880000E-01	0.0880000E-01	0.0860000E-01
0.0860000E-01	0.0860000E-01	0.0840000E-01
0.0840000E-01	0.0840000E-01	0.0820000E-01
0.0820000E-01	0.0820000E-01	0.0800000E-01
0.0800000E-01	0.0800000E-01	0.0780000E-01
0.0780000E-01	0.0780000E-01	0.0760000E-01
0.0760000E-01	0.0760000E-01	0.0740000E-01
0.0740000E-01	0.0740000E-01	0.0720000E-01
0.0720000E-01	0.0720000E-01	0.0700000E-01
0.0700000E-01	0.0700000E-01	0.0680000E-01
0.0680000E-01	0.0680000E-01	0.0660000E-01
0.0660000E-01	0.0660000E-01	0.0640000E-01
0.0640000E-01	0.0640000E-01	0.0620000E-01
0.0620000E-01	0.0620000E-01	0.0600000E-01
0.0600000E-01	0.0600000E-01	0.0580000E-01
0.0580000E-01	0.0580000E-01	0.0560000E-01
0.0560000E-01	0.0560000E-01	0.0540000E-01
0.0540000E-01	0.0540000E-01	0.0520000E-01
0.0520000E-01	0.0520000E-01	0.0500000E-01
0.0500000E-01	0.0500000E-01	0.0480000E-01
0.0480000E-01	0.0480000E-01	0.0460000E-01
0.0460000E-01	0.0460000E-01	0.0440000E-01
0.0440000E-01	0.0440000E-01	0.0420000E-01
0.0420000E-01	0.0420000E-01	0.0400000E-01
0.0400000E-01	0.0400000E-01	0.0380000E-01
0.0380000E-01	0.0380000E-01	0.0360000E-01
0.0360000E-01	0.0360000E-01	0.0340000E-01
0.0340000E-01	0.0340000E-01	0.0320000E-01
0.0320000E-01	0.0320000E-01	0.0300000E-01
0.0300000E-01	0.0300000E-01	0.0280000E-01
0.0280000E-01	0.0280000E-01	0.0260000E-01
0.0260000E-01	0.0260000E-01	0.0240000E-01
0.0240000E-01	0.0240000E-01	0.0220000E-01
0.0220000E-01	0.0220000E-01	0.0200000E-01
0.0200000E-01	0.0200000E-01	0.0180000E-01
0.0180000E-01	0.0180000E-01	0.0160000E-01
0.0160000E-01	0.0160000E-01	0.0140000E-01
0.0140000E-01	0.0140000E-01	0.0120000E-01
0.0120000E-01	0.0120000E-01	0.0100000E-01
0.0100000E-01	0.0100000E-01	0.0080000E-01
0.0080000E-01	0.0080000E-01	0.0060000E-01
0.0060000E-01	0.0060000E-01	0.0040000E-01
0.0040000E-01	0.0040000E-01	0.0020000E-01
0.0020000E-01	0.0020000E-01	0.0000000E-01

INTEGRAL = 0.5497629E 01  
PHOTOFRACTION = 0.1539029E 00

# NORMALIZED CONTINUUM OF STANDARD SPECTRA

CS137 SOURCE	ENERGY=	0.6616 MEV		
0.5338384E-01	0.53371992E-01	0.5335599E-01	0.5339206E-01	0.5322813E-01
0.5330420E-01	0.5329027E-01	0.5327335E-01	0.53257242E-01	0.5280497E-01
0.5322456E-01	0.5320854E-01	0.5319147E-01	0.5317527E-01	0.5158884E-01
0.5314492E-01	0.5312681E-01	0.5310970E-01	0.5309331E-01	0.5077692E-01
0.5306528E-01	0.5304508E-01	0.53027742E-01	0.53011349E-01	0.4994956E-01
0.5298564E-01	0.5296335E-01	0.529495774E-01	0.52929385E-01	0.49122992E-01
0.5290600E-01	0.5288162E-01	0.52863814E-01	0.5284742E-01	0.4831228E-01
0.5282636E-01	0.5280000E-01	0.527818494E-01	0.5276547E-01	0.4749063E-01
0.5274672E-01	0.5271837E-01	0.52695995E-01	0.52683492E-01	0.4667099E-01
0.5266708E-01	0.5263675E-01	0.52617921E-01	0.52601529E-01	0.4589142E-01
0.5258744E-01	0.52551586E-01	0.5252807E-01	0.52524029E-01	0.4505251E-01
0.5250780E-01	0.52467694E-01	0.52449174E-01	0.52430137E-01	0.4411359E-01
0.5242816E-01	0.5237803E-01	0.52359268E-01	0.52336246E-01	0.4317468E-01
0.5234852E-01	0.5228839E-01	0.5226945E-01	0.52246941E-01	0.42191643E-01
0.5226888E-01	0.5219873E-01	0.5218003E-01	0.52159609E-01	0.41208605E-01
0.5218924E-01	0.5210907E-01	0.5209033E-01	0.52069304E-01	0.40225567E-01
0.5210960E-01	0.5201941E-01	0.5200059E-01	0.51979079E-01	0.39242529E-01
0.5202996E-01	0.5192975E-01	0.5191079E-01	0.51889754E-01	0.38259491E-01
0.5195032E-01	0.5184009E-01	0.5182103E-01	0.51799585E-01	0.37276453E-01
0.5187068E-01	0.5175043E-01	0.5173137E-01	0.51698416E-01	0.36293415E-01
0.5179104E-01	0.5166077E-01	0.5164171E-01	0.51607247E-01	0.35310377E-01
0.5171140E-01	0.5157111E-01	0.5155205E-01	0.51516078E-01	0.34327339E-01
0.5163176E-01	0.5148145E-01	0.5146239E-01	0.51425039E-01	0.33344301E-01
0.5155212E-01	0.5139179E-01	0.5137273E-01	0.51334000E-01	0.32361263E-01
0.5147248E-01	0.5130213E-01	0.5128317E-01	0.51244201E-01	0.31378225E-01
0.5139284E-01	0.5121247E-01	0.5119341E-01	0.51153402E-01	0.30395187E-01
0.5131320E-01	0.5112281E-01	0.5110375E-01	0.51063393E-01	0.29412149E-01
0.5123356E-01	0.5103315E-01	0.5101409E-01	0.50973384E-01	0.28429111E-01
0.5115392E-01	0.5094349E-01	0.5092443E-01	0.50883375E-01	0.27446073E-01
0.5107428E-01	0.5085383E-01	0.5083477E-01	0.50793366E-01	0.26463035E-01
0.5099464E-01	0.5076417E-01	0.5074511E-01	0.50703357E-01	0.25480000E-01
0.5091500E-01	0.5067451E-01	0.5065545E-01	0.50613348E-01	0.24496965E-01
0.5083536E-01	0.5058485E-01	0.5056579E-01	0.50523139E-01	0.23513930E-01
0.5075572E-01	0.5049519E-01	0.5047613E-01	0.50432930E-01	0.22530895E-01
0.5067608E-01	0.5040553E-01	0.5038647E-01	0.50344721E-01	0.21547860E-01
0.5059644E-01	0.5031587E-01	0.5029681E-01	0.50254512E-01	0.20564825E-01
0.5051680E-01	0.5022621E-01	0.5020715E-01	0.50164303E-01	0.19581790E-01
0.5043716E-01	0.5013655E-01	0.5011709E-01	0.50074094E-01	0.18598755E-01
0.5035752E-01	0.5004689E-01	0.5002743E-01	0.50033885E-01	0.17615720E-01
0.5027788E-01	0.4995723E-01	0.4993777E-01	0.49893676E-01	0.16632685E-01
0.5019824E-01	0.4986757E-01	0.4984811E-01	0.49804467E-01	0.15649650E-01
0.5011860E-01	0.4977791E-01	0.4975845E-01	0.49715258E-01	0.14666615E-01
0.5003896E-01	0.4968825E-01	0.4966879E-01	0.49671049E-01	0.13683580E-01
0.4995932E-01	0.4959859E-01	0.4957913E-01	0.49536840E-01	0.12699545E-01
0.4987968E-01	0.4950893E-01	0.4948947E-01	0.49447541E-01	0.11715510E-01
0.4979904E-01	0.4941927E-01	0.4940001E-01	0.49358412E-01	0.10731475E-01
0.4971940E-01	0.4932961E-01	0.4931035E-01	0.49268263E-01	0.09747440E-01
0.4963976E-01	0.4923995E-01	0.4922069E-01	0.49178114E-01	0.08763405E-01
0.4956012E-01	0.4915029E-01	0.4913103E-01	0.49087965E-01	0.07779370E-01
0.4948048E-01	0.4906063E-01	0.4904137E-01	0.49007816E-01	0.06795335E-01
0.4940084E-01	0.4897097E-01	0.4895171E-01	0.48917667E-01	0.05811300E-01
0.4932120E-01	0.4888131E-01	0.4886205E-01	0.48827518E-01	0.04827265E-01
0.4924156E-01	0.4879165E-01	0.4877239E-01	0.48737369E-01	0.03843230E-01
0.4916192E-01	0.4870199E-01	0.4868273E-01	0.48647220E-01	0.02859195E-01
0.4908228E-01	0.4861233E-01	0.4859307E-01	0.48557071E-01	0.01875160E-01
0.4900264E-01	0.4852267E-01	0.4850341E-01	0.48466872E-01	0.00891125E-01
0.4892300E-01	0.4843301E-01	0.4841375E-01	0.48376673E-01	0.00000000E+00
0.4884336E-01	0.4834335E-01	0.4832409E-01	0.48279494E-01	0.00000000E+00
0.4876372E-01	0.4825369E-01	0.4823443E-01	0.48182315E-01	0.00000000E+00
0.4868408E-01	0.4816403E-01	0.4814477E-01	0.48095136E-01	0.00000000E+00
0.4860444E-01	0.4807437E-01	0.4805511E-01	0.48005937E-01	0.00000000E+00
0.4852480E-01	0.4798471E-01	0.4796545E-01	0.47916738E-01	0.00000000E+00
0.4844516E-01	0.4789505E-01	0.4787579E-01	0.47827539E-01	0.00000000E+00
0.4836552E-01	0.4780539E-01	0.4778613E-01	0.47738380E-01	0.00000000E+00
0.4828588E-01	0.4771573E-01	0.4769647E-01	0.47648121E-01	0.00000000E+00
0.4820624E-01	0.4762607E-01	0.4760681E-01	0.47559922E-01	0.00000000E+00
0.4812660E-01	0.4753641E-01	0.4751715E-01	0.47471723E-01	0.00000000E+00
0.4804696E-01	0.4744675E-01	0.4742749E-01	0.47379494E-01	0.00000000E+00
0.4796732E-01	0.4735709E-01	0.4733783E-01	0.47291255E-01	0.00000000E+00
0.4788768E-01	0.4726743E-01	0.4724817E-01	0.47193016E-01	0.00000000E+00
0.4780804E-01	0.4717777E-01	0.4715851E-01	0.47107757E-01	0.00000000E+00
0.4772840E-01	0.4708811E-01	0.4706885E-01	0.47016918E-01	0.00000000E+00
0.4764876E-01	0.4700000E-01	0.4698074E-01	0.46928979E-01	0.00000000E+00
0.4756912E-01	0.4691000E-01	0.4689074E-01	0.46839240E-01	0.00000000E+00
0.4748948E-01	0.4682000E-01	0.4680074E-01	0.46758701E-01	0.00000000E+00
0.4740984E-01	0.4673000E-01	0.4671074E-01	0.46668162E-01	0.00000000E+00
0.4733020E-01	0.4664000E-01	0.4662074E-01	0.46567623E-01	0.00000000E+00
0.4725056E-01	0.4655000E-01	0.4653074E-01	0.46487084E-01	0.00000000E+00
0.4717092E-01	0.4646000E-01	0.4644074E-01	0.46406545E-01	0.00000000E+00
0.4709128E-01	0.4637000E-01	0.4635074E-01	0.46336006E-01	0.00000000E+00
0.4701164E-01	0.4628000E-01	0.4626074E-01	0.46205467E-01	0.00000000E+00
0.4693200E-01	0.4619000E-01	0.4617074E-01	0.46130928E-01	0.00000000E+00
0.4685236E-01	0.4610000E-01	0.4608074E-01	0.46051389E-01	0.00000000E+00
0.4677272E-01	0.4601000E-01	0.4599074E-01	0.46001850E-01	0.00000000E+00
0.4669308E-01	0.4592000E-01	0.4590074E-01	0.45952311E-01	0.00000000E+00
0.4661344E-01	0.4583000E-01	0.4581074E-01	0.45862772E-01	0.00000000E+00
0.4653380E-01	0.4574000E-01	0.4572074E-01	0.45773233E-01	0.00000000E+00
0.4645416E-01	0.4565000E-01	0.4563074E-01	0.45683694E-01	0.00000000E+00
0.4637452E-01	0.4556000E-01	0.4554074E-01	0.45594155E-01	0.00000000E+00
0.4629488E-01	0.4547000E-01	0.4545074E-01	0.45504616E-01	0.00000000E+00
0.4621524E-01	0.4538000E-01	0.4536074E-01	0.45415077E-01	0.00000000E+00
0.4613560E-01	0.4529000E-01	0.4527074E-01	0.45325538E-01	0.00000000E+00
0.4605596E-01	0.4520000E-01	0.4518074E-01	0.45235999E-01	0.00000000E+00
0.4597632E-01	0.4511000E-01	0.4509074E-01	0.45146460E-01	0.00000000E+00
0.4589668E-01	0.4502000E-01	0.4500074E-01	0.45056921E-01	0.00000000E+00
0.4581704E-01	0.4493000E-01	0.4491074E-01	0.44967382E-01	0.00000000E+00
0.4573740E-01	0.4484000E-01	0.4482074E-01	0.44877843E-01	0.00000000E+00
0.4565776E-01	0.4475000E-01	0.4473074E-01	0.44788304E-01	0.00000000E+00
0.4557812E-01	0.4466000E-01	0.4464074E-01	0.44698765E-01	0.00000000E+00
0.4549848E-01	0.4457000E-01	0.4455074E-01	0.44609226E-01	0.00000000E+00
0.4541884E-01	0.4448000E-01	0.4446074E-01	0.44519687E-01	0.00000000E+00
0.4533920E-01	0.4439000E-01	0.4437074E-01	0.44430148E-01	0.00000000E+00
0.4525956E-01	0.4430000E-01	0.4428074E-01	0.44340609E-01	0.00000000E+00
0.4517992E-01	0.4421000E-01	0.4419074E-01	0.44251070E-01	0.00000000E+00
0.4510028E-01	0.4412000E-01	0.4410074E-01	0.44161531E-01	0.00000000E+00
0.4502064E-01	0.4403000E-01	0.4401074E-01	0.44071992E-01	0.00000000E+00
0.4494100E-01	0.4394000E-01	0.4392074E-01	0.43982453E-01	0.00000000E+00
0.4486136E-01	0.4385000E-01	0.4383074E-01	0.43892914E-01	0.00000000E+00
0.4478172E-01	0.4376000E-01	0.4374074E-01	0.43803375E-01	0.00000000E+00
0.4470208E-01	0.4367000E-01	0.4365074E-01	0.43713836E-01	0.00000000E+00
0.4462244E-01	0.4358000E-01	0.4356074E-01	0.43624297E-01	0.00000000E+00
0.4454280E-01	0.4349000E-01	0.4347074E-01	0.43534758E-01	0.00000000E+00
0.4446316E-01	0.4340000E-01	0.4338074E-01	0.43445219E-01	0.00000000E+00
0.4438352E-01	0.4331000E-01	0.4329074E-01	0.43355680E-01	0.00000000E+00
0.4430388E-01	0.4322000E-01	0.4320074E-01	0.43266141E-01	0.00000000E+00
0.4422424E-01	0.4313000E-01	0.4311074E-01	0.43176602E-01	0.00000000E+00
0.4414460E-01	0.4304000E-01	0.4302074E-01	0.43087063E-01	0.00000000E+00
0.4406496E-01	0.4295000E-01	0.4293074E-01	0.42997524E-01	0.00000000E+00
0.4398532E-01	0.4286000E-01	0.4284074E-01	0.42907985E-01	0.00000000E+00
0.4390568E-01	0.4277000E-01	0.4275074E-01	0.42818446E-01	0.00000000E+00
0.4382604E-01	0.4268000E-01	0.4266074E-01	0.42728907E-01	0.00000000E+00
0.4374640E-01	0.4259000E-01	0.4257074E-01	0.42639368E-01	0.00000000E+00
0.4366676E-01	0.4250000E-01	0.4248074E-01	0.42549829E-01	0.00000000E+00
0.4358712E-01	0.4241000E-01	0.4239074E-01	0.42460290E-01	0.00000000E+00
0.4350748E-01	0.4232000E-01	0.4230074E-01	0.42370751E-01	0.00000000E+00
0.4342784E-01	0.4223000E-01	0.4221074E-01	0.42281212E-01	0.00000000E+00
0.4334820E-01	0.4214000E-01	0.4212074E-01	0.42191673E-01	0.00000000E+00
0.4326856E-01	0.4205000E-01	0.4203074E-01	0.42102134E-01	0.00000000E+00
0.4318892E-01	0.4196000E-01	0.4194074E-01	0.420	

# NORMALIZED CONTINUUM OF STANDARD SPECTRA

MS4 SOURCE	ENERGY=	0.2350 MEV
0.7146639E-01	0.7112385E-01	0.7079136E-01
0.6977880E-01	0.6944132E-01	0.6910378E-01
0.6809127E-01	0.6775373E-01	0.6741625E-01
0.6640369E-01	0.6606615E-01	0.6539112E-01
0.6471610E-01	0.6437862E-01	0.6404108E-01
0.6302851E-01	0.6269103E-01	0.6235354E-01
0.6134100E-01	0.6100348E-01	0.6066597E-01
0.5965343E-01	0.5931592E-01	0.5897840E-01
0.5796586E-01	0.5762835E-01	0.5752129E-01
0.5618762E-01	0.5574304E-01	0.5529853E-01
0.5439682E-01	0.5352027E-01	0.5307571E-01
0.5216205E-01	0.5113055E-01	0.5078984E-01
0.4999013E-01	0.5149357E-01	0.4884670E-01
0.5037209E-01	0.5049241E-01	0.4949379E-01
0.4700489E-01	0.4777449E-01	0.4660361E-01
0.4543683E-01	0.4610644E-01	0.4468428E-01
0.4367451E-01	0.4294793E-01	0.4269093E-01
0.4466891E-01	0.4337737E-01	0.4167658E-01
0.4396275E-01	0.4205638E-01	0.4313800E-01
0.4355510E-01	0.4195492E-01	0.4334656E-01
0.4315998E-01	0.4398338E-01	0.4254818E-01
0.4228470E-01	0.4295163E-01	0.4466919E-01
0.4468964E-01	0.4555946E-01	0.4524531E-01
0.4544358E-01	0.4545355E-01	0.4612123E-01
0.4637014E-01	0.4827130E-01	0.4818564E-01
0.5022516E-01	0.5099901E-01	0.5071764E-01
0.5333655E-01	0.5444314E-01	0.5562412E-01
0.5988150E-01	0.6056262E-01	0.6143489E-01
0.6581306E-01	0.6510413E-01	0.6966848E-01
0.7142955E-01	0.7395571E-01	0.7459706E-01
0.7533157E-01	0.7259887E-01	0.6467843E-01
0.3692580E-01	0.3441921E-01	0.3224223E-01
0.2879783E-01	0.2686582E-01	0.2520756E-01
0.2157826E-01	0.2051659E-01	0.1954781E-01
0.1440072E-01	0.1270784E-01	0.1094949E-01
0.8334998E-02	0.7311318E-02	0.6919141E-02
0.5302289E-02	0.5849320E-02	0.5636312E-02
0.5119443E-02	0.5422050E-02	0.5275492E-02
0.4688419E-02	0.5024115E-02	0.5777354E-02
0.7150784E-02	0.7785735E-02	0.1159447E-01
0.0	0.0	0.0
0.0	0.0	0.0

INTEGRAL = 0.9286665E-01  
PHOTOFRACTION = 0.9914765E-01

# NUPMALIZED CONTINUUM OF STANDARD SPECTRA

MS4 SOURCE	ENERGY=	1.1140 MEV
0.9963143E-01	0.9888941E-01	0.9814733E-01
0.9592128E-01	0.9517026E-01	0.9443724E-01
0.9221119E-01	0.9146017E-01	0.9072715E-01
0.8950110E-01	0.8775008E-01	0.8701706E-01
0.8479100E-01	0.8404899E-01	0.8330657E-01
0.8108091E-01	0.8033890E-01	0.7959688E-01
0.7737382E-01	0.7652880E-01	0.7588679E-01
0.7403451E-01	0.7311843E-01	0.7218243E-01
0.6943392E-01	0.6847775E-01	0.6755161E-01
0.6276080E-01	0.6164545E-01	0.6067590E-01
0.6367889E-01	0.6416742E-01	0.6237483E-01
0.5953762E-01	0.5735733E-01	0.5787399E-01
0.5750898E-01	0.5418062E-01	0.5845556E-01
0.5356597E-01	0.5131336E-01	0.5324853E-01
0.5064119E-01	0.4996662E-01	0.5216709E-01
0.5222915E-01	0.4933984E-01	0.5103994E-01
0.5163782E-01	0.5223332E-01	0.4932692E-01
0.5115931E-01	0.5296799E-01	0.4982828E-01
0.5277585E-01	0.5294118E-01	0.5314652E-01
0.5228733E-01	0.5040746E-01	0.5118219E-01
0.5206602E-01	0.5191464E-01	0.5031504E-01
0.5265837E-01	0.5506377E-01	0.5371463E-01
0.5243644E-01	0.5407704E-01	0.5473644E-01
0.5047924E-01	0.5437500E-01	0.5521953E-01
0.5376363E-01	0.5797713E-01	0.5956979E-01
0.5992288E-01	0.5915427E-01	0.6098215E-01
0.5947195E-01	0.6135174E-01	0.6197880E-01
0.6655955E-01	0.6731606E-01	0.6673563E-01
0.6947633E-01	0.7267731E-01	0.7547683E-01
0.7943764E-01	0.8157137E-01	0.9132774E-01
0.8728744E-01	0.9034903E-01	0.9188771E-01
0.1013212E-02	0.1078974E-02	0.1118244E-02
0.1108307E-02	0.1015655E-02	0.8044249E-02
0.5059813E-01	0.4995613E-01	0.4955381E-01
0.3766962E-01	0.3805585E-01	0.3210271E-01
0.2618993E-01	0.2344627E-01	0.2048833E-01
0.1357049E-01	0.1144842E-01	0.1069719E-01
0.7142468E-02	0.6899791E-02	0.7237109E-02
0.6356616E-02	0.6832257E-02	0.7524241E-02
0.7909963E-02	0.9497905E-02	0.1240705E-01
0.1449145E-03	0.2777379E-03	0.1351299E-03
0.0	0.0	0.0
0.0	0.0	0.0

INTEGRAL = 0.1196219E-02  
PHOTOFRACTION = 0.7714742E-01

# NORMALIZED CONTINUUM OF STANDARD SPECTRA

C650 SOURCE	ENERGY=	1.3300 MEV
0.1208785E-01	0.1192651E-00	0.1176518E-00
0.1128117E-00	0.1111984E-00	0.1095850E-00
0.1067449E-00	0.1031316E-00	0.1015182E-00
0.9667814E-01	0.9506476E-01	0.9345144E-01
0.8861130E-01	0.8699799E-01	0.8538467E-01
0.8054459E-01	0.7893121E-01	0.7692705E-01
0.7551455E-01	0.7425702E-01	0.7209954E-01
0.6811609E-01	0.6814879E-01	0.6637764E-01
0.6093143E-01	0.6758505E-01	0.6584524E-01
0.6293764E-01	0.6124275E-01	0.5976218E-01
0.60383419E-01	0.6159427E-01	0.5819190E-01
0.5428543E-01	0.5274102E-01	0.5130265E-01
0.5772097E-01	0.5665066E-01	0.5584640E-01
0.5163722E-01	0.5227648E-01	0.5359657E-01
0.5224746E-01	0.5342990E-01	0.5388422E-01
0.5367247E-01	0.5141248E-01	0.5201121E-01
0.4943162E-01	0.4740973E-01	0.4541321E-01
0.5325719E-01	0.5219654E-01	0.5076420E-01
0.5509555E-01	0.5347962E-01	0.5222255E-01
0.5136822E-01	0.5105477E-01	0.5163771E-01
0.5362312E-01	0.5623136E-01	0.5765478E-01
0.5766998E-01	0.6057231E-01	0.5929879E-01
0.5814005E-01	0.5879057E-01	0.5697773E-01
0.6255456E-01	0.6134104E-01	0.5997950E-01
0.6165228E-01	0.6218078E-01	0.6354713E-01
0.6472278E-01	0.6319213E-01	0.6511867E-01
0.6749611E-01	0.6876109E-01	0.6402392E-01
0.6904948E-01	0.7002133E-01	0.6743258E-01
0.7358998E-01	0.7414857E-01	0.7555783E-01
0.7839335E-01	0.8072507E-01	0.7943654E-01
0.8918929E-01	0.8755481E-01	0.9063147E-01
0.9560764E-01	0.9922932E-01	0.1013579E-00
0.1048199E-00	0.1134004E-00	0.1153187E-00
0.1263106E-00	0.1211647E-00	0.1212733E-00
0.1681928E-01	0.1765035E-01	0.1743355E-01
0.1947710E-01	0.1964527E-01	0.1982645E-01
0.2469871E-01	0.2116434E-01	0.1831211E-01
0.1132163E-01	0.9893389E-02	0.9349763E-02
0.8334405E-02	0.8485655E-02	0.8093222E-02
0.9722355E-02	0.9906265E-02	0.1356297E-01
0.0	0.0	0.0
0.0	0.0	0.0

INTEGRAL = 0.1305978E-02  
PHOTOFRACTION = 0.7112837E-01

# NORMALIZED CONTINUUM OF STANDARD SPECTRA

TH228 SOURCE	ENERGY=	2.6150 MEV
0.2033437E-00	0.2075241E-00	0.2055085E-00
0.1940295E-00	0.1960984E-00	0.1939649E-00
0.1874229E-00	0.1847767E-00	0.1826946E-00
0.1772685E-00	0.1750852E-00	0.1733237E-00
0.1630926E-00	0.1641431E-00	0.1647282E-00
0.1507116E-00	0.1581721E-00	0.1566623E-00
0.1518419E-00	0.1505689E-00	0.1489934E-00
0.1445256E-00	0.1431929E-00	0.1419139E-00
0.1364182E-00	0.1376308E-00	0.1363469E-00
0.1337825E-00	0.1328946E-00	0.1321393E-00
0.1296643E-00	0.1296124E-00	0.1283697E-00
0.1262057E-00	0.1255229E-00	0.1248939E-00
0.1233385E-00	0.1227096E-00	0.1220670E-00
0.1216185E-00	0.1202109E-00	0.1155819E-00
0.1145062E-00	0.1196055E-00	0.1127140E-00
0.1129866E-00	0.1144783E-00	0.1152354E-00
0.1117531E-00	0.1105791E-00	0.1134189E-00
0.1114944E-00	0.1106114E-00	0.1105130E-00
0.1222507E-00	0.1303120E-00	0.1215298E-00
0.1242229E-00	0.1278067E-00	0.1227448E-00
0.1188889E-00	0.1225103E-00	0.1249353E-00
0.1126001E-00	0.1256789E-00	0.1195911E-00
0.1132913E-00	0.1286121E-00	0.1136409E-00
0.1273546E-00	0.1188084E-00	0.1122406E-00
0.1144017E-00	0.1145029E-00	0.1151318E-00
0.1185486E-00	0.1194774E-00	0.1208063E-00
0.1241929E-00	0.1253217E-00	0.1264507E-00
0.1298537E-00	0.1309824E-00	0.1321110E-00
0.1354969E-00	0.1366256E-00	0.1377542E-00
0.1411677E-00	0.1422989E-00	0.1414270E-00
0.1468135E-00	0.1474420E-00	0.1450070E-00
0.1524739E-00	0.1536154E-00	0.1547440E-00
0.1581299E-00	0.1592585E-00	0.1614780E-00
0.1717321E-00	0.1755243E-00	0.1736642E-00
0.1924354E-00	0.1953530E-00	0.2022944E-00
0.2211213E-00	0.2114844E-00	0.2452977E-00
0.2427595E-00	0.2212747E-00	0.1612645E-00
0.1115284E-00	0.1048286E-00	0.951634E-01
0.4507381E-01	0.3310415E-01	0.2420966E-01
0.1727150E-01	0.1901723E-01	0.2250212E-01
0.6765541E-02	0.2541623E-02	0.2287373E-02
0.0	0.0	0.0
0.0	0.0	0.0

INTEGRAL = 0.275537E-02  
PHOTOFRACTION = 0.350213E-01





0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4908E-01	0.7975E-01	0.7667E-01	0.6936E-01	0.5430E-01	0.4664E-01	0.4672E-01	0.4744E-01	0.4836E-01	0.589E-01
0.5547E-01	0.6438E-01	0.8304E-01	0.7160E-01	0.2568E-01	0.7674E-02	0.807CE-01	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8677E-01	0.7551E-01	0.7159E-01	0.6491E-01	0.5008E-01	0.4571E-01	0.4325E-01	0.4276E-01	0.4431E-01	0.4697E-01
0.4944E-01	0.5398E-01	0.6273E-01	0.8048E-01	0.6995E-01	0.2517E-01	0.7590E-02	0.7832E-01	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4443E-01	0.7264E-01	0.6865E-01	0.5956E-01	0.4714E-01	0.4280E-01	0.4070E-01	0.3906E-01	0.4034E-01	0.4295E-01
0.4457E-01	0.4818E-01	0.5241E-01	0.6122E-01	0.7777E-01	0.6886E-01	0.2443E-01	0.7422E-02	0.7586E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8218E-01	0.7003E-01	0.6379E-01	0.5665E-01	0.4524E-01	0.3996E-01	0.3842E-01	0.3720E-01	0.3709E-01	0.3809E-01
0.4230E-01	0.4453E-01	0.4710E-01	0.5112E-01	0.5989E-01	0.7488E-01	0.6769E-01	0.2334E-01	0.7198E-02	0.7341E-01
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.7964E-01	0.6773E-01	0.5997E-01	0.5429E-01	0.4338E-01	0.3744E-01	0.3655E-01	0.3588E-01	0.3394E-01	0.3558E-01
0.7777E-01	0.4145E-01	0.4309E-01	0.6612E-01	0.4997E-01	0.5862E-01	0.7178E-01	0.6613E-01	0.2281E-01	0.6928E-02
0.7044E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.7712E-01	0.6563E-01	0.5973E-01	0.5016E-01	0.4119E-01	0.3623E-01	0.3428E-01	0.3351E-01	0.3295E-01	0.3308E-01
0.3351E-01	0.3845E-01	0.4027E-01	0.4194E-01	0.4528E-01	0.4832E-01	0.5727E-01	0.6820E-01	0.6488E-01	0.2214E-01
0.6636E-02	0.6846E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.7459E-01	0.6366E-01	0.5739E-01	0.4869E-01	0.3803E-01	0.3594E-01	0.3150E-01	0.3247E-01	0.3255E-01	0.3051E-01
0.3256E-01	0.3284E-01	0.3760E-01	0.3974E-01	0.4100E-01	0.4428E-01	0.4818E-01	0.5586E-01	0.6485E-01	0.6316E-01
0.2159E-01	0.6397E-02	0.6603E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.7198E-01	0.6175E-01	0.5556E-01	0.4702E-01	0.3631E-01	0.3540E-01	0.3068E-01	0.3124E-01	0.3084E-01	0.3004E-01
0.3011E-01	0.3071E-01	0.3398E-01	0.3682E-01	0.3869E-01	0.4025E-01	0.4311E-01	0.4762E-01	0.5440E-01	0.6196E-01
0.6129E-01	0.2044E-01	0.2165E-02	0.6361E-01	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.6939E-01	0.5994E-01	0.5404E-01	0.4530E-01	0.3516E-01	0.3507E-01	0.3046E-01	0.2978E-01	0.2910E-01	0.3027E-01
0.2812E-01	0.3304E-01	0.2915E-01	0.3473E-01	0.3597E-01	0.3757E-01	0.3964E-01	0.4206E-01	0.4747E-01	0.5292E-01
0.5767E-01	0.5978E-01	0.1997E-01	0.6071E-02	0.6124E-01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.6677E-01	0.5796E-01	0.5270E-01	0.4365E-01	0.3506E-01	0.3343E-01	0.3059E-01	0.2679E-01	0.2899E-01	0.2902E-01
0.2810E-01	0.2786E-01	0.2900E-01	0.2381E-01	0.3333E-01	0.3584E-01	0.3678E-01	0.3895E-01	0.4125E-01	0.4652E-01
0.5149E-01	0.5318E-01	0.5627E-01	0.1561E-01	0.5874E-02	0.5891E-01	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.6417E-01	0.5612E-01	0.5146E-01	0.4209E-01	0.3516E-01	0.3146E-01	0.3046E-01	0.2716E-01	0.2808E-01	0.2699E-01
0.2944E-01	0.2653E-01	0.2860E-01	0.2727E-01	0.3055E-01	0.3292E-01	0.3505E-01	0.3597E-01	0.3835E-01	0.4058E-01
0.4695E-01	0.5018E-01	0.5114E-01	0.5499E-01	0.1916E-01	0.5662E-02	0.567E-01	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.6157E-01	0.5421E-01	0.5024E-01	0.4064E-01	0.3499E-01	0.3315E-01	0.3086E-01	0.2748E-01	0.2554E-01	0.2696E-01
0.2758E-01	0.2681E-01	0.2637E-01	0.2791E-01	0.2655E-01	0.3124E-01	0.3216E-01	0.3413E-01	0.3516E-01	0.3773E-01
0.3987E-01	0.4536E-01	0.4897E-01	0.4642E-01	0.5281E-01	0.1831E-01	0.5507E-02	0.5445E-01	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5904E-01	0.5235E-01	0.4898E-01	0.3904E-01	0.3464E-01	0.2972E-01	0.3048E-01	0.2757E-01	0.2453E-01	0.2693E-01
0.2583E-01	0.2704E-01	0.2540E-01	0.2707E-01	0.2621E-01	0.2722E-01	0.3569E-01	0.3184E-01	0.3329E-01	0.3452E-01
0.3794E-01	0.3924E-01	0.4474E-01	0.4638E-01	0.4171E-01	0.5086E-01	0.1813E-01	0.5171E-02	0.5233E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5656E-01	0.5954E-01	0.4764E-01	0.3836E-01	0.3425E-01	0.3004E-01	0.2915E-01	0.2747E-01	0.2543E-01	0.2538E-01
0.2529E-01	0.2638E-01	0.2591E-01	0.2528E-01	0.2665E-01	0.2524E-01	0.2755E-01	0.2975E-01	0.3188E-01	0.3206E-01
0.3397E-01	0.3628E-01	0.3667E-01	0.4421E-01	0.4734E-01	0.3813E-01	0.4697E-01	0.1797E-01	0.5117E-02	0.5030E-01
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.6411E-01	0.4472E-01	0.4614E-01	0.3738E-01	0.3385E-01	0.3337E-01	0.2788E-01	0.2797E-01	0.2580E-01	0.2618E-01
0.2568E-01	0.2499E-01	0.2592E-01	0.2432E-01	0.2558E-01	0.2587E-01	0.2473E-01	0.2791E-01	0.2889E-01	0.3096E-01
0.3198E-01	0.3348E-01	0.3549E-01	0.3808E-01	0.4356E-01	0.4692E-01	0.3562E-01	0.4253E-01	0.1794E-01	0.4079E-02
0.4831E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5178E-01	0.4694E-01	0.4385E-01	0.3733E-01	0.3347E-01	0.3049E-01	0.2731E-01	0.2803E-01	0.2579E-01	0.2376E-01
0.2552E-01	0.2414E-01	0.2533E-01	0.2513E-01	0.2442E-01	0.2572E-01	0.2451E-01	0.2496E-01	0.2767E-01	0.2839E-01
0.3023E-01	0.3136E-01	0.3245E-01	0.3472E-01	0.3756E-01	0.4289E-01	0.4686E-01	0.3234E-01	0.3809E-01	0.1793E-01
0.4726E-02	0.4644E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4945E-01	0.4513E-01	0.4236E-01	0.3633E-01	0.3310E-01	0.3035E-01	0.2728E-01	0.2742E-01	0.2566E-01	0.2444E-01
0.2339E-01	0.2455E-01	0.2421E-01	0.2455E-01	0.2435E-01	0.2456E-01	0.2506E-01	0.2396E-01	0.2483E-01	0.2302E-01
0.2807E-01	0.2953E-01	0.3068E-01	0.3223E-01	0.3398E-01	0.3609E-01	0.4216E-01	0.4690E-01	0.2977E-01	0.3644E-01
0.1551E-01	0.4595E-02	0.4480E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.4725E-01	0.4347E-01	0.4043E-01	0.3548E-01	0.3273E-01	0.3318E-01	0.2756E-01	0.2658E-01	0.2599E-01	0.2467E-01
0.2292E-01	0.2444E-01	0.2331E-01	0.2436E-01	0.2439E-01	0.2384E-01	0.2478E-01	0.2416E-01	0.2332E-01	0.2487E-01
0.2629E-01	0.2775E-01	0.2891E-01	0.3007E-01	0.3163E-01	0.3327E-01	0.3626E-01	0.4141E-01	0.4696E-01	0.2879E-01
0.3174E-01	0.1495E-01	0.4496E-02	0.4397E-01	0.0	0.0	0.0	0.0	0.0	0.0
0.4512E-01	0.4172E-01	0.3899E-01	0.3572E-01	0.3233E-01	0.2992E-01	0.2775E-01	0.2607E-01	0.2675E-01	0.2455E-01
0.2338E-01	0.2322E-01	0.2358E-01	0.2353E-01	0.2437E-01	0.2394E-01	0.2382E-01	0.2435E-01	0.2323E-01	0.2321E-01
0.2444E-01	0.2564E-01	0.2727E-01	0.2834E-01	0.2949E-01	0.3105E-01	0.3256E-01	0.3351E-01	0.4260E-01	0.4693E-01
0.2854E-01	0.2617E-01	0.1187E-01	0.4229E-02	0.4141E-01	0.0	0.0	0.0	0.0	0.0
0.4308E-01	0.4034E-01	0.3750E-01	0.3421E-01	0.3189E-01	0.2964E-01	0.2775E-01	0.2598E-01	0.2574E-01	0.2450E-01
0.2377E-01	0.2267E-01	0.2190E-01	0.2255E-01	0.2350E-01	0.2365E-01	0.2361E-01	0.2374E-01	0.2358E-01	0.2309E-01
0.2265E-01	0.2426E-01	0.2516E-01	0.2669E-01	0.2779E-01	0.2893E-01	0.3036E-01	0.3186E-01	0.3495E-01	0.3974E-01
0.4679E-01	0.2870E-01	0.2100E-01	0.1283E-01	0.3920E-02	0.3984E-01	0.0	0.0	0.0	0.0
0.4113E-01	0.3850E-01	0.3598E-01	0.3350E-01	0.3135E-01	0.2937E-01	0.2764E-01	0.2607E-01	0.2537E-01	0.2458E-01
0.2378E-01	0.2244E-01	0.2284E-01	0.2289E-01	0.2294E-01	0.2323E-01	0.2352E-01	0.2316E-01	0.2378E-01	0.2284E-01
0.2234E-01	0.2242E-01	0.2376E-01	0.2479E-01	0.2611E-01	0.2725E-01	0.2840E-01	0.2971E-01	0.3118E-01	0.3426E-01
0.3884E-01	0.4626E-01	0.2995E-01	0.1754E-01	0.1009E-01	0.3604E-02	0.3834E-01	0.0	0.0	0.0
0.3924E-01	0.3694E-01	0.3464E-01	0.3251E-01	0.3076E-01	0.2904E-01	0.2747E-01	0.2612E-01	0.2516E-01	0.2445E-01
0.2367E-01	0.2356E-01	0.2332E-01	0.2293E-01	0.2215E-01	0.2267E-01	0.2293E-01	0.2334E-01	0.2320E-01	0.2313E-01
0.2322E-01	0.2251E-01	0.2212E-01	0.2124E-01	0.2437E-01	0.2556E-01	0.2670E-01	0.2784E-01	0.2905E-01	0.3047E-01
0.3354E-01	0.3726E-01	0.4526E-01	0.1187E-01	0.1563E-01	0.6625E-02	0.3009E-02	0.3690E-01	0.0	0.0
0.3746E-01	0.3545E-01	0.3347E-01	0.3170E-01	0.3013E-01	0.2867E-01	0.2726E-01	0.2607E-01	0.2517E-01	0.2422E-01
0.2363E-01	0.2333E-01	0.2256E-01	0.2279E-01	0.2218E-01	0.2222E-01	0.2238E-01	0.2295E-01	0.2287E-01	0.2295E-01
0.2210E-01	0.2247E-01	0.2114E-01	0.2166E-01	0.2281E-01	0.2391E-01	0.2504E-01	0.2618E-01	0.2732E-01	0.2844E-01

RESPONSE MATRIX ENERGY INTERVAL MIDPOINTS IN MEV

0.0344 0.1033 0.1722 0.2411 0.3099 0.3788 0.4477 0.5166 0.5854 0.6543  
0.7232 0.7921 0.8609 0.9298 0.9987 1.0676 1.1364 1.2053 1.2742 1.3431  
1.4119 1.4808 1.5497 1.6186 1.6874 1.7563 1.8252 1.8941 1.9629 2.0318  
2.1007 2.1696 2.2384 2.3073 2.3762 2.4451 2.5139 2.5828 2.6517 2.7206

PULSE-HEIGHT IN CHANNELS (MIDPOINTS)

0.50 1.50 2.50 3.50 4.50 5.50 6.50 7.50 8.50 9.50  
10.50 11.50 12.50 13.50 14.50 15.50 16.50 17.50 18.50 19.50  
20.50 21.50 22.50 23.50 24.50 25.50 26.50 27.50 28.50 29.50  
30.50 31.50 32.50 33.50 34.50 35.50 36.50 37.50 38.50 39.50

RESPONSE MATRIX PHOTOFRACTIONS

0.8652 0.6814 0.5321 0.3651 0.2678 0.2089 0.1735 0.1500 0.1341 0.1214  
0.1111 0.1024 0.0946 0.0877 0.0824 0.0783 0.0758 0.0741 0.0722 0.0702  
0.0682 0.0661 0.0640 0.0618 0.0597 0.0575 0.0554 0.0533 0.0513 0.0494  
0.0474 0.0456 0.0437 0.0420 0.0403 0.0387 0.0372 0.0357 0.0343 0.0329

INDEX	ENERGY	STD. DEV
1	0.0	0.0
2	0.1659999E 00	0.1707057E 01
3	0.2790000E 00	0.1007876E 01
4	0.5140000E 00	0.5605643E 00
5	0.6616000E 00	0.4791170E 00
6	0.8350000E 00	0.3917066E 00
7	0.1113999E 01	0.3136572E 00
8	0.1330000E 01	0.3161970E 00
9	0.2615000E 01	0.2511438E 00

GAMMA SOURCE	SOURCE STRENGTH (CURIES)	REFERENCE ENERGY (MEV)	SOURCE DIAMETER (CM.)	SOURCE HALF-LIFE (MINUTES)	NUMBER OF PHA RUNS THIS SET	NUMBER OF CHANNELS PER SPECTRUM	HALF-LIFE MULTIPLIER
TM228	1.0000	2.0150	1.0000	0.5260E 07	1	400	0.5260E 06

M22	M6	MZ	MNX	MBX	MSM	MS	MX
0	0	25	0	0	0	27	395

SOURCE CRYSTAL DISTANCE (CM)	COUNTING DURATION (MINUTES)	REFERENCE TIME (DAYS)	SPECTRA ZERO SHIFT (CHANNELS)	BACKGROUND SIGNAL	BACKGROUND MULTIPLIER
32.0000	10.0000	1.0000	0.0	0.0	0.0

ITERATING OUTPUT ON ITERATION LOOPS NUMBERED BELOW

1	3	5	7	9
10	15	20	25	30
0	0	0	0	0
0	0	0	0	0

(AFTER BACKGROUND SUBTRACTION)

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5057.	9609.	12015.	12709.	12785.	12294.	11802.	11155.	10264.	9699.
9156.	8323.	7568.	6905.	6791.	5632.	5267.	4923.	4416.	4165.
3848.	3631.	3287.	3075.	2942.	3708.	2572.	2170.	2051.	1983.
1998.	1885.	1678.	1649.	1550.	1428.	1358.	1252.	1330.	1167.
1215.	1315.	1253.	982.	880.	897.	849.	818.	771.	765.
891.	717.	701.	673.	698.	638.	609.	553.	589.	578.
533.	561.	511.	485.	548.	625.	459.	491.	467.	457.
422.	460.	460.	428.	427.	648.	384.	411.	431.	470.
363.	358.	361.	325.	343.	349.	355.	356.	330.	335.
339.	374.	369.	331.	329.	280.	351.	287.	302.	278.
317.	299.	274.	260.	271.	255.	279.	237.	264.	243.
246.	213.	226.	224.	213.	254.	205.	199.	209.	202.
225.	252.	252.	285.	195.	221.	219.	205.	219.	199.
238.	126.	219.	195.	193.	191.	177.	189.	189.	227.
191.	191.	216.	199.	199.	191.	198.	189.	190.	190.
136.	179.	179.	211.	197.	223.	182.	201.	212.	193.
191.	210.	219.	193.	222.	212.	212.	218.	258.	234.
246.	178.	150.	140.	137.	134.	134.	113.	107.	112.
42.	98.	95.	110.	43.	75.	76.	68.	54.	60.
50.	58.	63.	64.	57.	55.	64.	51.	42.	40.
52.	82.	885.	392.	39.	33.	33.	36.	38.	25.
13.	25.	40.	26.	34.	23.	24.	23.	19.	24.
29.	79.	69.	23.	31.	26.	40.	43.	30.	26.
22.	18.	17.	27.	16.	29.	25.	16.	23.	20.
22.	23.	26.	19.	18.	21.	59.	31.	20.	25.
17.	16.	22.	23.	16.	25.	10.	23.	27.	20.
16.	21.	23.	26.	22.	21.	19.	20.	23.	25.
21.	23.	22.	17.	24.	10.	24.	16.	14.	14.
14.	15.	13.	19.	15.	13.	9.	20.	10.	25.
15.	13.	18.	16.	16.	26.	26.	14.	19.	13.
15.	23.	14.	19.	22.	16.	13.	17.	20.	25.
29.	17.	19.	20.	20.	13.	21.	17.	20.	15.
21.	17.	15.	18.	19.	21.	16.	17.	19.	21.
16.	23.	21.	23.	20.	22.	19.	9.	7.	10.
7.	12.	10.	6.	10.	17.	6.	6.	15.	4.
5.	8.	7.	4.	6.	1.	5.	3.	3.	3.
6.	1.	1.	0.	4.	1.	6.	6.	8.	96.
53.	6.	2.	1.	0.	0.	0.	0.	1.	2.
1.	2.	1.	2.	3.	3.	0.	1.	0.	0.

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6.	6.	7.	0.	0.	0.	0.	0.	0.	0.
6.	6.	6.	6.	6.	6.	6.	6.	6.	6.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3540.	3631.	3287.	3075.	2902.	3770.	5632.	5269.	4923.	4414.
1598.	1685.	1678.	1649.	1550.	1428.	3770.	3572.	3270.	2051.
1215.	1115.	1283.	982.	886.	897.	849.	818.	771.	765.
401.	717.	771.	673.	698.	638.	609.	563.	589.	578.
533.	561.	511.	485.	548.	625.	459.	499.	467.	457.
422.	460.	462.	426.	427.	640.	384.	411.	431.	470.
363.	358.	361.	325.	343.	349.	355.	356.	330.	335.
339.	374.	320.	331.	320.	280.	351.	287.	302.	278.
317.	299.	274.	264.	271.	255.	270.	237.	244.	243.
246.	213.	276.	224.	213.	254.	205.	199.	239.	202.
225.	210.	290.	293.	195.	221.	214.	275.	219.	199.
234.	276.	210.	195.	193.	187.	177.	189.	180.	227.
191.	191.	206.	193.	199.	191.	198.	188.	190.	190.
180.	179.	179.	231.	197.	223.	182.	271.	232.	193.
191.	210.	219.	193.	222.	232.	218.	218.	258.	234.
246.	178.	150.	140.	137.	134.	134.	113.	170.	112.
92.	68.	95.	110.	83.	75.	76.	68.	54.	60.
50.	58.	63.	64.	57.	55.	64.	51.	42.	46.
52.	82.	985.	302.	34.	33.	30.	36.	19.	25.
33.	25.	47.	24.	34.	21.	24.	23.	19.	24.
29.	74.	64.	23.	31.	26.	40.	43.	30.	26.
22.	14.	17.	27.	10.	24.	25.	16.	23.	20.
22.	23.	26.	19.	14.	23.	59.	31.	20.	25.
17.	16.	22.	23.	16.	25.	10.	23.	27.	20.
16.	21.	23.	24.	22.	21.	19.	20.	23.	25.
21.	23.	22.	17.	24.	10.	24.	16.	14.	14.
14.	15.	13.	19.	15.	11.	9.	20.	10.	25.
15.	13.	18.	16.	15.	26.	26.	14.	19.	13.
15.	23.	14.	19.	22.	14.	13.	17.	20.	25.
29.	17.	19.	20.	20.	13.	21.	17.	20.	15.
21.	17.	15.	13.	19.	21.	18.	17.	19.	21.
10.	23.	21.	23.	20.	22.	19.	9.	7.	10.
7.	17.	17.	6.	15.	17.	6.	6.	15.	4.
5.	6.	7.	4.	6.	1.	5.	3.	3.	3.
6.	1.	1.	0.	4.	1.	6.	6.	8.	90.
53.	0.	2.	1.	0.	0.	0.	0.	1.	2.
1.	2.	1.	2.	3.	3.	0.	1.	7.	0.

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# EFFICIENCY FACTORS

INDEX	ENERGY (MEV)	AIR ATTENUATION	ABSORBER ATTENUATION	CRYSTAL EFFICIENCY	TOTAL EFFICIENCY
1	0.24451E 00	0.99527E 00	0.76257E 00	0.83176E 00	0.63127E 00

PHOTON NUMBER	=	0.4192742E 04
PHOTOFRACTION	=	0.3593062E 00

# DISCRETE PHOTOPEAK FITTING DATA

LOCATION CHANNEL TO CHANNEL	ENERGY (MEV)	PULSE-HEIGHT (CHANNELS)	STANDARD DEVIATION (CHANNELS)	AREA (COUNTS/TIME)
35 37	0.2445061E 00	0.3550000E 02	0.0	0.9510700E 03



# EFFICIENCY FACTORS

INDEX	ENERGY (MEV)	AIR ATTENUATION	ABSORBER ATTENUATION	CRYSTAL EFFICIENCY	TOTAL EFFICIENCY
2	0.58888E 00	0.99665E 00	0.82671E 00	0.65423E 00	0.53905E 00

PHOTON NUMBER	=	0.3260663E 04
PHOTOFRACTION	=	0.1334171E 00

# DISCRETE PHOTOPEAK FITTING DATA

LOCATION CHANNEL TO CHANNEL	ENERGY (MEV)	PULSE-HEIGHT (CHANNELS)	STANDARD DEVIATION (CHANNELS)	AREA (COUNTS/TIME)
45 47	0.5888878E 00	0.8550000E 02	0.0	0.2345000E 01



# EFFICIENCY FACTORS

INDEX	ENERGY (MEV)	AIR ATTENUATION	ABSORBER ATTENUATION	CRYSTAL EFFICIENCY	TOTAL EFFICIENCY
3	0.61643E 02	0.99672E 02	0.82983E 02	0.64623E 00	0.53450E 00

PHOTON NUMBER	=	0.3988115E 04
PHOTOFRACTION	=	0.1280698E 00

## DISCRETE PHOTOPEAK FITTING DATA

LOCATION CHANNEL TO CHANNEL	ENERGY (MEV)	PULSE-HEIGHT (CHANNELS)	STANDARD DEVIATION (CHANNELS)	AREA (COUNTS/TIME)
89 91	0.6164308E 00	0.8950002E 02	0.0	0.2739000E 03



# EFFICIENCY FACTORS

INDEX	ENERGY (MEV)	AIR ATTENUATION	ABSORBER ATTENUATION	CRYSTAL EFFICIENCY	TOTAL EFFICIENCY
4	0.14656E 01	0.59784E 02	0.88431E 02	0.49655E 00	0.43815E 00

PHOTON NUMBER	=	0.3968964E 05
PHOTOFRACTION	=	0.6653214E -01

## DISCRETE PHOTOPEAK FITTING DATA

LOCATION CHANNEL TO CHANNEL	ENERGY (MEV)	PULSE-HEIGHT (CHANNELS)	STANDARD DEVIATION (CHANNELS)	AREA (COUNTS/TIME)
212 215	0.1465612E 01	0.2127933E 03	0.0	0.1157602E 04



## GAIN PARAMETERS AFTER CALL DISCRT IN MAIN

0.0	400	400.0000	40.0000	0.0	0.0	0.0	0.0	0.0	0.0
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3652.	3439.	3111.	2915.	2792.	2638.	2455.	2055.	1937.	1856.
1887.	1773.	1565.	1534.	1434.	1311.	1190.	1136.	1215.	1054.
1104.	1204.	1171.	868.	763.	779.	731.	760.	655.	654.
696.	615.	602.	580.	610.	553.	525.	482.	512.	505.
463.	492.	443.	418.	492.	559.	393.	433.	401.	391.
356.	395.	396.	364.	364.	346.	325.	353.	374.	343.
307.	301.	302.	267.	285.	291.	265.	295.	268.	273.
278.	265.	252.	274.	269.	222.	292.	227.	241.	215.
252.	233.	207.	200.	201.	185.	200.	168.	190.	176.
178.	144.	155.	152.	140.	182.	133.	127.	167.	130.
152.	137.	217.	210.	121.	147.	144.	139.	143.	122.
160.	247.	140.	115.	113.	106.	96.	108.	108.	146.
109.	108.	121.	112.	111.	102.	108.	97.	98.	96.
91.	81.	77.	127.	93.	118.	77.	95.	125.	84.
79.	96.	102.	73.	97.	102.	83.	79.	118.	94.
109.	47.	27.	28.	38.	46.	57.	44.	45.	56.
41.	51.	56.	76.	54.	55.	55.	53.	38.	46.
37.	47.	52.	54.	47.	45.	54.	41.	32.	36.
43.	82.	67.	53.	38.	31.	30.	36.	38.	25.
33.	25.	47.	28.	34.	23.	24.	23.	19.	24.
29.	79.	68.	23.	31.	26.	40.	43.	30.	26.
22.	18.	17.	27.	16.	28.	25.	16.	23.	20.
22.	21.	26.	19.	18.	23.	59.	31.	20.	25.
17.	16.	22.	23.	16.	25.	10.	23.	27.	20.
16.	21.	23.	28.	22.	21.	19.	20.	23.	25.
21.	23.	22.	17.	24.	10.	24.	16.	14.	14.
14.	15.	13.	19.	15.	13.	9.	20.	10.	25.
15.	13.	18.	16.	16.	26.	26.	14.	19.	13.
15.	23.	14.	19.	22.	18.	13.	17.	20.	25.
29.	17.	19.	20.	20.	13.	21.	17.	20.	15.
21.	17.	15.	18.	15.	21.	18.	17.	19.	21.
16.	23.	21.	23.	20.	22.	19.	9.	7.	10.
7.	12.	10.	6.	19.	17.	6.	6.	15.	4.
5.	8.	7.	4.	6.	1.	5.	3.	3.	3.
6.	1.	1.	0.	4.	1.	6.	6.	8.	96.
53.	0.	2.	1.	0.	0.	0.	0.	1.	2.
1.	2.	1.	2.	3.	3.	0.	1.	0.	0.

## SUBTRACTED DISCRETE PEAK PHOTON NUMBER FLUX

INDEX	ENERGY (MEV)	NUMBER FLUX (PHOTONS/CM**2-SEC)
1	0.2445961E 00	0.8373457E 03
2	0.5988808E 00	0.6311977E 00
3	0.6164398E 01	0.7964801E 00
4	0.1465612E 01	0.7926548E 01

INPUT SPECTRUM GAIN CHANGED TO 40 CHANNELS  
GAIN CHANGE RATIO = 400.00000/ 40.00000

0.0	0.0	0.2347911E 05	0.2684916E 05	0.1409902E 05
0.8629164E 04	0.5690239E 04	0.4475867E 04	0.3616177E 04	0.2884473E 04
0.2535301E 04	0.2013488E 04	0.1506749E 04	0.1522471E 04	0.1339065E 04
0.1002192E 04	0.5684143E 03	0.9234124E 03	0.4983355E 03	0.5176294E 03
0.4436489E 03	0.4452463E 03	0.2730000E 03	0.3950300E 03	0.2120000E 03
0.2660000E 03	0.1993703E 03	0.2180000E 03	0.1850300E 03	0.1530000E 03
0.1760000E 03	0.1860000E 03	0.1910000E 03	0.1860000E 03	0.1700000E 03
0.9300000E 02	0.4500000E 02	0.1290000E 03	0.5990000E 02	0.1300000E 02

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# EFFICIENCY FACTORS

INDEX	ENERGY (MEV)	AIR ATTENUATION	ABSORBER ATTENUATION	CRYSTAL EFFICIENCY	TOTAL EFFICIENCY
1	0.34437E-01	0.98795E 00	0.15704E 00	0.99872E 00	0.15495E 00
2	0.10331E 00	0.99366E 00	0.68011E 00	0.97665E 00	0.66072E 00
3	0.17219E 00	0.99422E 00	0.73160E 00	0.91306E 00	0.66440E 00
4	0.24106E 00	0.99524E 00	0.76148E 00	0.83510E 00	0.63289E 00
5	0.30994E 00	0.99567E 00	0.78090E 00	0.77223E 00	0.60042E 00
6	0.37881E 00	0.99598E 00	0.77550E 00	0.73306E 00	0.58080E 00
7	0.44769E 00	0.99624E 00	0.80746E 00	0.70255E 00	0.56515E 00
8	0.51656E 00	0.99646E 00	0.81761E 00	0.67711E 00	0.55165E 00
9	0.58544E 00	0.99664E 00	0.82630E 00	0.65529E 00	0.53964E 00
10	0.65431E 00	0.99680E 00	0.83387E 00	0.63575E 00	0.52844E 00
11	0.72319E 00	0.99695E 00	0.84053E 00	0.61779E 00	0.51768E 00
12	0.79206E 00	0.99707E 00	0.84650E 00	0.60161E 00	0.50786E 00
13	0.86094E 00	0.99718E 00	0.85247E 00	0.58828E 00	0.50008E 00
14	0.92981E 00	0.99728E 00	0.85732E 00	0.57518E 00	0.49178E 00
15	0.99869E 00	0.99737E 00	0.86152E 00	0.56241E 00	0.48377E 00
16	0.10676E 01	0.99745E 00	0.86538E 00	0.55037E 00	0.47577E 00
17	0.11364E 01	0.99753E 00	0.86906E 00	0.53900E 00	0.46727E 00
18	0.12053E 01	0.99760E 00	0.87257E 00	0.52836E 00	0.45935E 00
19	0.12742E 01	0.99767E 00	0.87591E 00	0.51889E 00	0.45344E 00
20	0.13431E 01	0.99773E 00	0.87909E 00	0.51056E 00	0.44781E 00
21	0.14119E 01	0.99779E 00	0.88209E 00	0.50255E 00	0.44232E 00
22	0.14808E 01	0.99785E 00	0.88491E 00	0.49489E 00	0.43699E 00
23	0.15497E 01	0.99790E 00	0.88732E 00	0.48799E 00	0.43209E 00
24	0.16186E 01	0.99794E 00	0.88953E 00	0.48151E 00	0.42744E 00
25	0.16874E 01	0.99798E 00	0.89168E 00	0.47527E 00	0.42293E 00
26	0.17563E 01	0.99803E 00	0.89375E 00	0.46930E 00	0.41860E 00
27	0.18252E 01	0.99807E 00	0.89574E 00	0.46359E 00	0.41445E 00
28	0.18941E 01	0.99810E 00	0.89766E 00	0.45817E 00	0.41050E 00
29	0.19629E 01	0.99814E 00	0.89950E 00	0.45305E 00	0.40676E 00
30	0.20318E 01	0.99818E 00	0.90112E 00	0.44855E 00	0.40347E 00
31	0.21007E 01	0.99821E 00	0.90254E 00	0.44461E 00	0.40056E 00
32	0.21696E 01	0.99824E 00	0.90391E 00	0.44080E 00	0.39774E 00
33	0.22384E 01	0.99828E 00	0.90526E 00	0.43710E 00	0.39501E 00
34	0.23073E 01	0.99833E 00	0.90657E 00	0.43353E 00	0.39236E 00
35	0.23762E 01	0.99837E 00	0.90784E 00	0.43009E 00	0.38980E 00
36	0.24451E 01	0.99836E 00	0.90908E 00	0.42678E 00	0.38735E 00
37	0.25139E 01	0.99839E 00	0.91028E 00	0.42364E 00	0.38511E 00
38	0.25828E 01	0.99841E 00	0.91145E 00	0.42070E 00	0.38284E 00
39	0.26517E 01	0.99843E 00	0.91259E 00	0.41787E 00	0.38074E 00
40	0.27206E 01	0.99845E 00	0.91369E 00	0.41515E 00	0.37873E 00

## DIFFERENTIAL FLUX AT ITERATION NUMBER = 23

0.2	0.0	0.58285E 04	0.63146E 05	0.41037E 05
0.25555E 05	0.15487E 05	0.15341E 05	0.17914E 05	0.14937E 05
0.11691E 05	0.59386E 04	0.13457E 04	0.59201E 04	0.92311E 04
0.91382E 04	0.91256E 04	0.98815E 04	0.12625E 03	0.13874E 04
0.10891E 04	0.51470E 04	0.97073E 03	0.70399E 04	0.17568E 04
0.22847E 04	0.21358E 02	0.64994E 02	0.89960E 00	0.66656E 02
0.16235E 03	0.53036E 00	0.98336E 00	0.44577E 02	0.21279E 04
0.18887E 04	0.17407E 04	0.89841E 04	0.43361E 04	0.10017E 04

## SINGLE SPECTRUM 40 CHANNELS

C.	C.	23479.	26849.	14399.	8629.	5680.	4476.	3616.	2884.
2535.	2018.	1507.	1522.	1339.	1062.	968.	923.	498.	518.
444.	445.	273.	355.	212.	266.	199.	218.	155.	153.
176.	186.	191.	186.	170.	93.	45.	129.	59.	13.



# NUMBER AND ENERGY SPECTRUM AT THE CRYSTAL

INCREMENT	ENERGY (KEV)	NUMBER FLUX (PHOTONS/CM**2-SEC)	ENERGY FLUX (KEV/CM**2-SEC)
1	0.03444	0.0	0.0
2	0.10331	0.0	0.0
3	0.17219	0.1163864E 01	0.2004027E 00
4	0.24106	0.1260876E 02	0.3039497E 01
5	0.30994	0.8194021E 01	0.2539633E 01
6	0.37881	0.5102632E 01	0.1932958E 01
7	0.44769	0.3092307E 01	0.1384388E 01
8	0.51656	0.3262915E 01	0.1685498E 01
9	0.58544	0.3577054E 01	0.2094140E 01
10	0.65431	0.2682470E 01	0.1951468E 01
11	0.72319	0.2374355E 01	0.1717102E 01
12	0.79206	0.1185794E 01	0.9392222E 00
13	0.86094	0.2686644E 00	0.2313306E 00
14	0.92981	0.1182099E 01	0.1099130E 01
15	1.09869	0.1843223E 01	0.1849801E 01
16	1.16756	0.1824664E 01	0.1947940E 01
17	1.13644	0.1822183E 01	0.2070770E 01
18	1.20531	0.1773426E 01	0.2137529E 01
19	1.27419	0.2523994E-01	0.3212213E-01
20	1.34306	0.2770238E 00	0.3720597E 00
21	1.41194	0.2174669E 00	0.3070493E 00
22	1.48081	0.1027729E 01	0.1521872E 01
23	1.54969	0.1438300E 00	0.3003755E 00
24	1.61856	0.1405691E 01	0.2275196E 01
25	1.68744	0.3507823E-01	0.5919223E-01
26	1.75631	0.4561951E 00	0.8012202E 00
27	1.82518	0.4264582E-02	0.7783648E-02
28	1.89406	0.1297759E-01	0.2458752E-01
29	1.96294	0.1796286E-03	0.3525992E-03
30	2.03181	0.1332953E-05	0.2704242E-05
31	2.10069	0.3741778E-04	0.6809954E-04
32	2.16956	0.9997376E-14	0.2167581E-13
33	2.23843	0.1962937E-03	0.4393889E-03
34	2.30731	0.8901004E-02	0.2053737E-01
35	2.37618	0.4248816E 00	0.1009597E 01
36	2.44506	0.3771341E 00	0.9221153E 00
37	2.51394	0.3475731E 00	0.8737762E 00
38	2.58281	0.1753910E 01	0.4633327E 01
39	2.65169	0.8658088E 00	0.2295852E 01
40	2.72056	0.2000070E 00	0.5441334E 00

## INTEGRATED RESULTS AT SOURCE AND CRYSTAL

### ENERGY INTEGRATED PHOTON (BREMS.) VALUES AT THE CRYSTAL

PHOTON NUMBER (PHOTONS/CM\*\*2-SEC) = 0.5993245E 02  
 PHOTON ENERGY (KEV/CM\*\*2-SEC) = 0.4281345E 02  
 PHOTON DOSE (ROENTGENS/HOUR) = 0.7778591E-04

AVERAGE ENERGY (KEV) = 0.7143617E 00

PHOTON NUMBER / SOURCE EMITTED BETA NUMBER (PHOTONS/CM\*\*2-SEC)/(BETA/SEC) = 0.1619796E-08  
 PHOTON ENERGY / SOURCE EMITTED BETA ENERGY ((KEV/CM\*\*2-SEC)/(BETA/SEC)) = 0.1637225E 02  
 PHOTON ENERGY / SOURCE EMITTED BETA NUMBER ((KEV/CM\*\*2-SEC)/(BETA/SEC)) = 0.1157120E-08  
 PHOTON DOSE / SOURCE EMITTED BETA NUMBER ((R/HR)/(BETA/SEC)) = 0.2132322E-14  
 PHOTON DOSE / SOURCE EMITTED BETA NUMBER PER SOURCE VOLUME (((R/HR)/(BETA/SEC))/CM\*\*3) = 0.2676760E-14

### AT THE SOURCE CYLINDER

PHOTON DOSE / SOURCE EMITTED BETA NUMBER (R/HR)/(BETA/SEC) = 0.3247201E-11  
 PHOTON DOSE / SOURCE EMITTED BETA NUMBER PER SOURCE VOLUME (((R/HR)/(BETA/SEC))/CM\*\*3) = 0.4134665E-11

APPENDIX V

PHOTOPEAK AND BACKSCATTER PEAK DISTRIBUTIONS

## APPENDIX V

### Photopeak and Backscatter Peak Distributions

Figures V-1 through V-8 give the residual spectral count distributions in the photopeak region after systematic fitting and subtraction of the Gaussian function. The residuals are approximately zero at channels greater than the Gaussian mean pulse height. For  $\text{Ce}^{139}$  and  $\text{Hg}^{203}$  the residuals below mean pulse height are as expected, i.e., the Compton tail appears regular in shape. The Compton tail of the other standards exhibits peak asymmetry, perhaps associated with Ge(Li) electron-hole trapping. A more detailed analysis was not possible within the economic constraints of the present work.

Figures V-9 through V-17 (generated by subroutine XPLOT) give the generally very good agreement between the fitted Gaussian function (zeros' i.e., 0) and the experimental photopeaks (ex's i.e., x); the asterisks indicate x and o superimposed. In these figures the true photopeak channel is obtained by adding the figure specified-number to plot channels (at bottom of figure).

Figure V-18 shows the normalized backscatter peak distributions, with respect to unit pulse height (200 channels) and photopeak area. These peaks were obtained after fitting a straight line base through counts on both sides of the peak region (see FITLIN description in Section 2.2.2.4). All peaks exhibit a regular shape pattern with the exception of  $\text{Ce}^{139}$ ;  $\text{Ce}^{139}$  continuum counts were statistically poor and thus this may account in part for spurious region between channels 10 and 20 in Figure V-18. Figure V-19 presents the backscatter peak height as a function of energy. The behaviour is seen to be satisfactorily regular.

Ce<sup>139</sup>, E = 0.166 MeV  
Maximum Count = 40,357

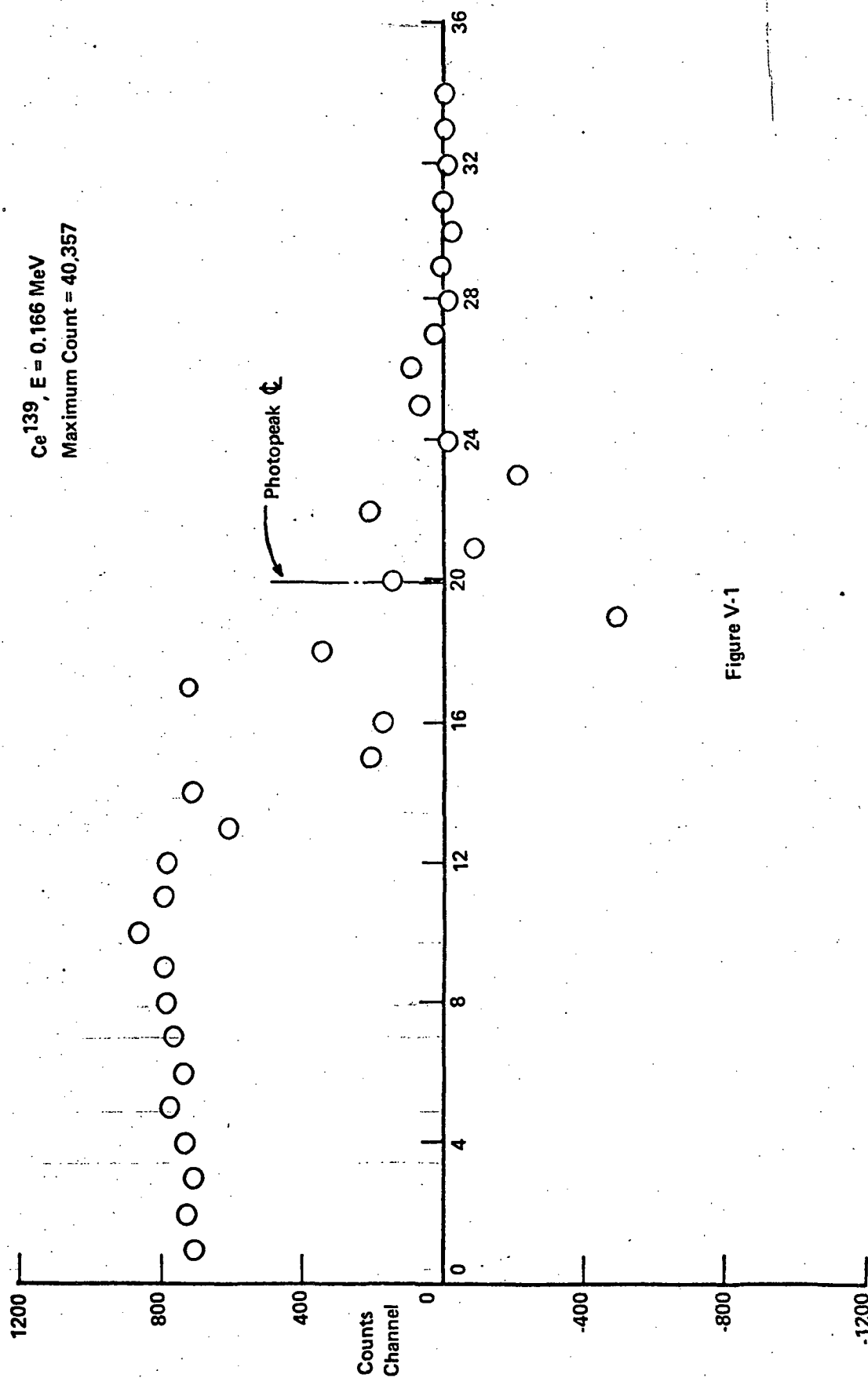


Figure V-1

$\text{Hg}^{203}$ ,  $E = 0.279 \text{ MeV}$   
Maximum Count = 7,493

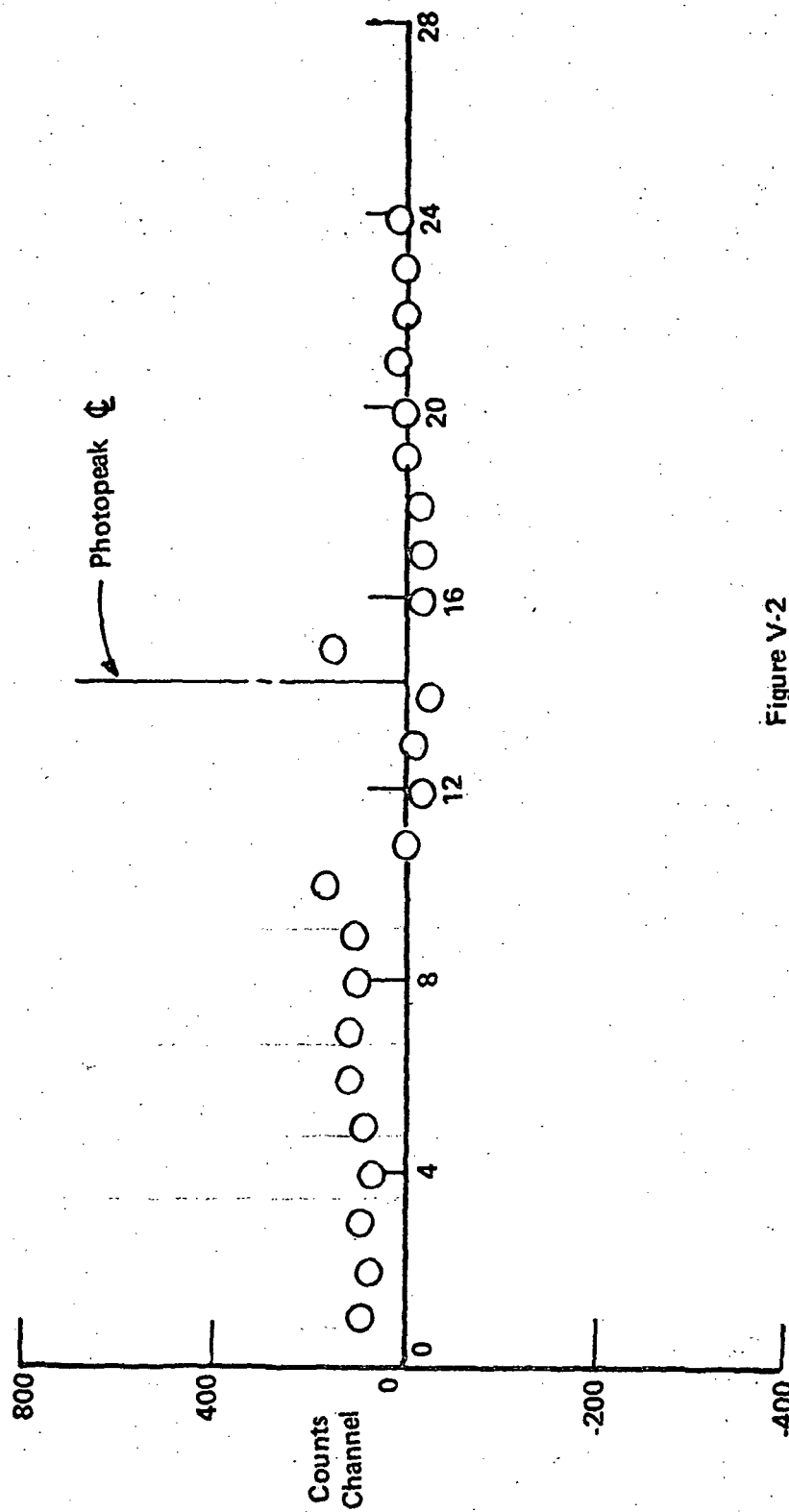


Figure V-2

$Sr^{85}$ ,  $E = 0.514 \text{ MeV}$   
 Maximum Count = 31,361

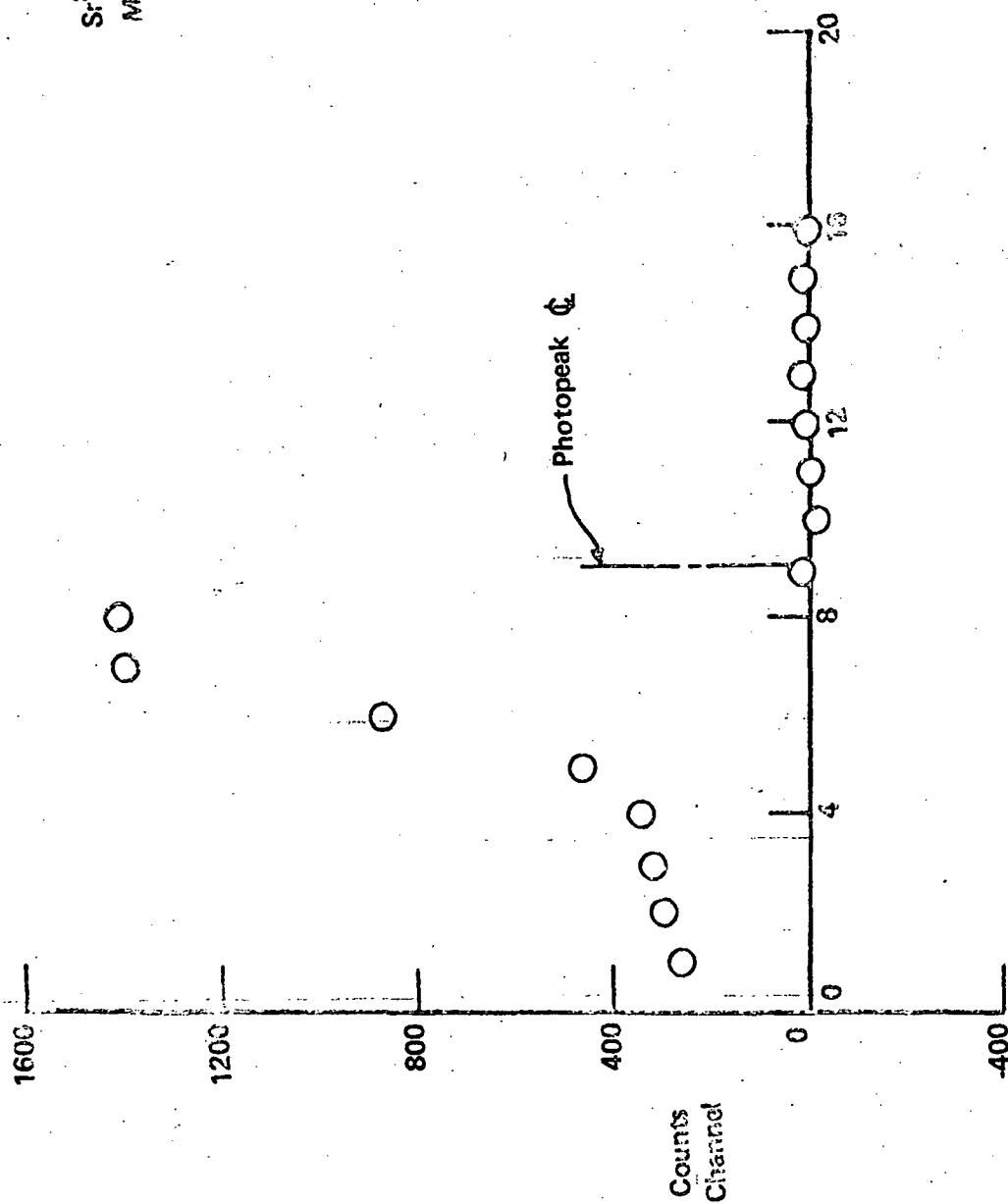


Figure V-3

$\text{Cs}^{137}$ ,  $E = 0.6616 \text{ MeV}$   
Maximum Count = 79,962

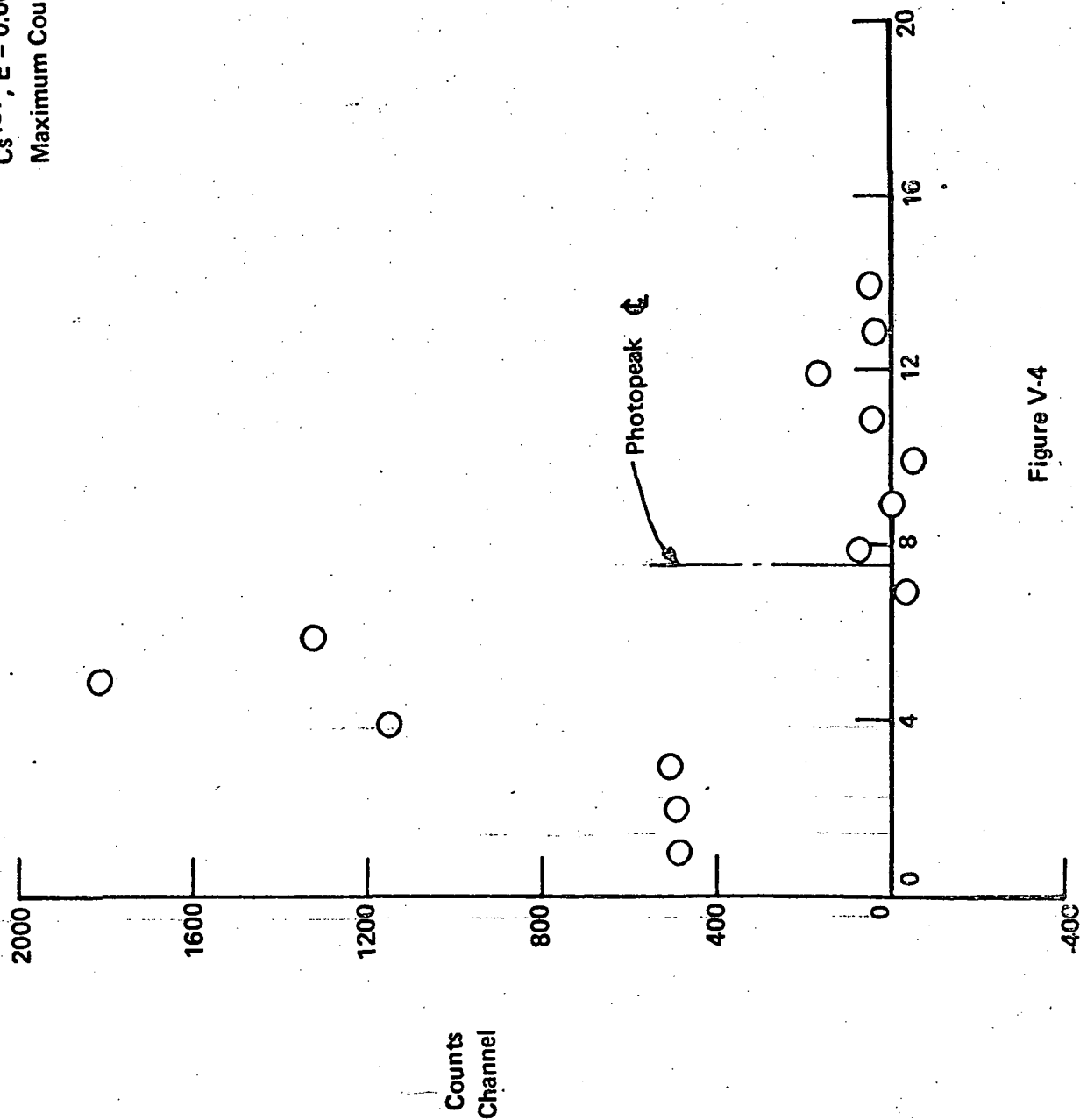


Figure V-4

$Mn^{54}$ ,  $E = 0.835$  MeV  
Maximum Counts = 46,336

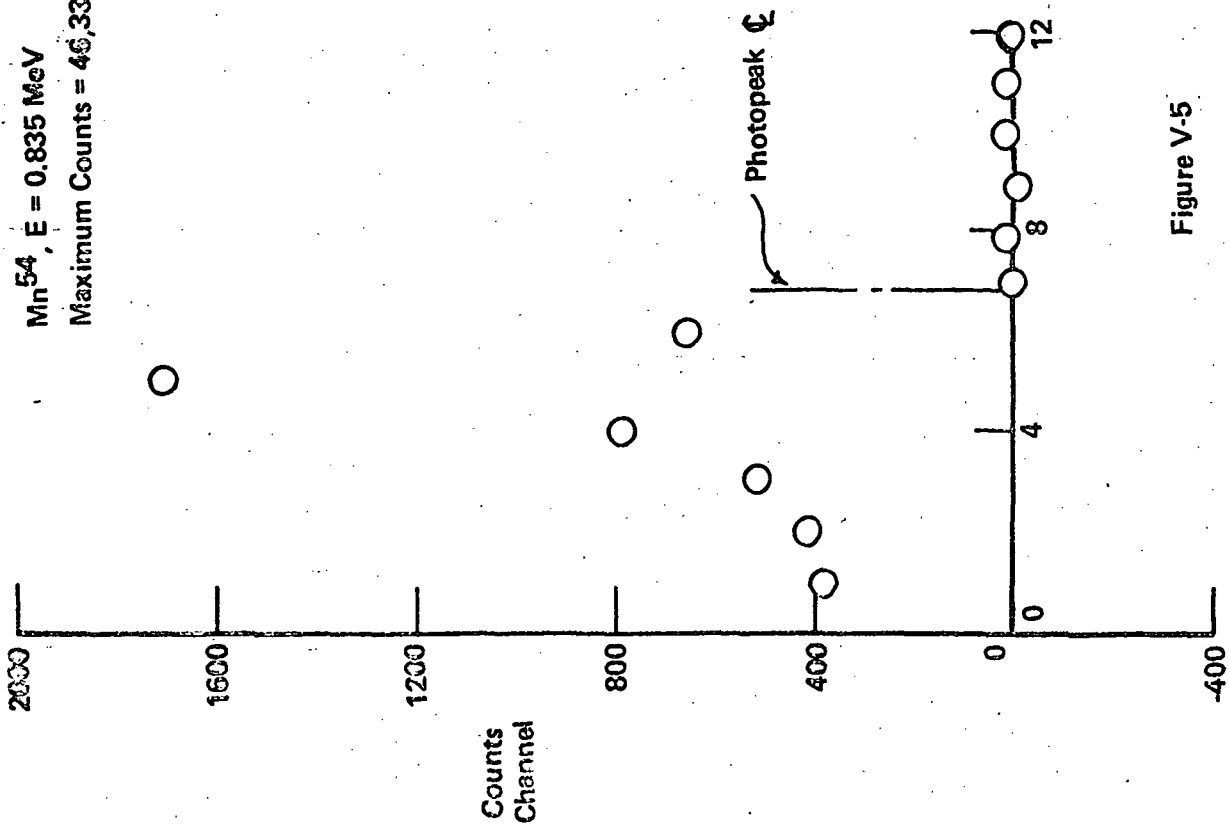


Figure V-5

$Zn^{65}$ ,  $E = 1.114$  MeV  
Maximum Count = 16,691

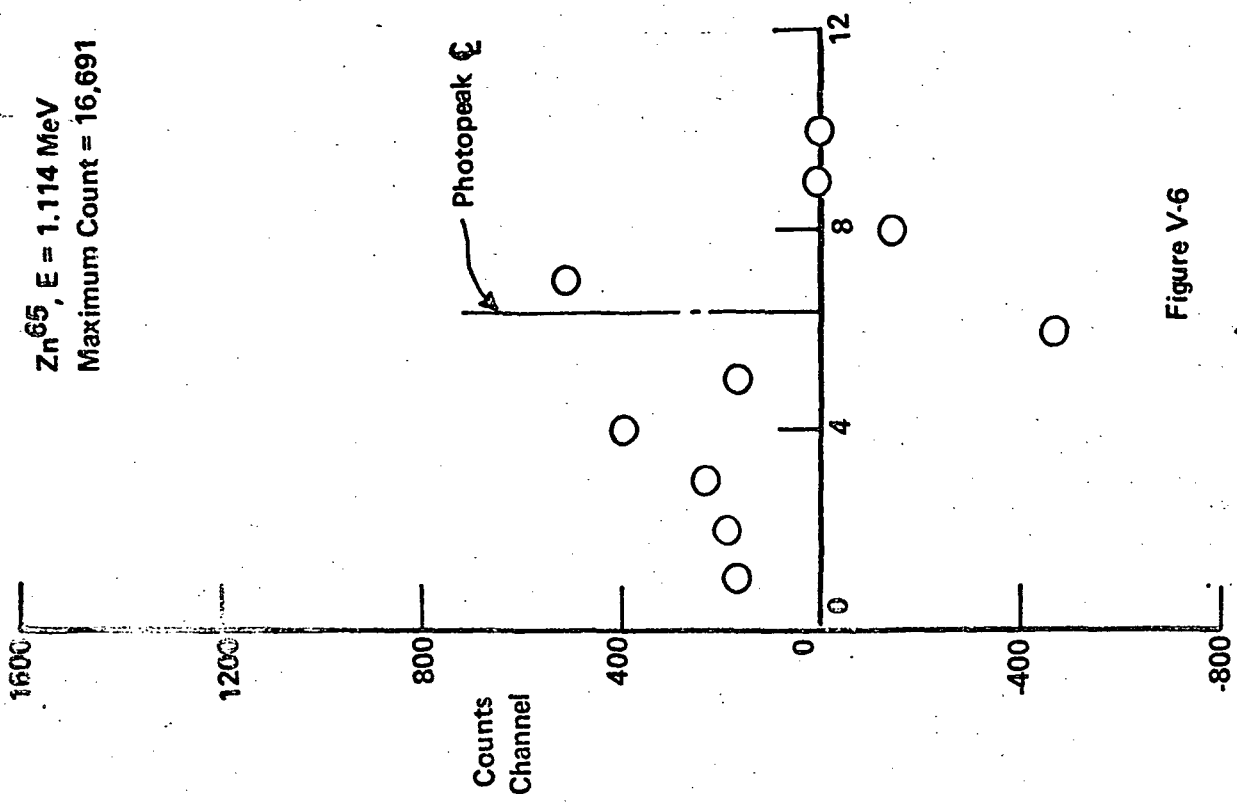


Figure V-6



Na<sup>22</sup>, E = 1.28 MeV  
Maximum Count = 50,548

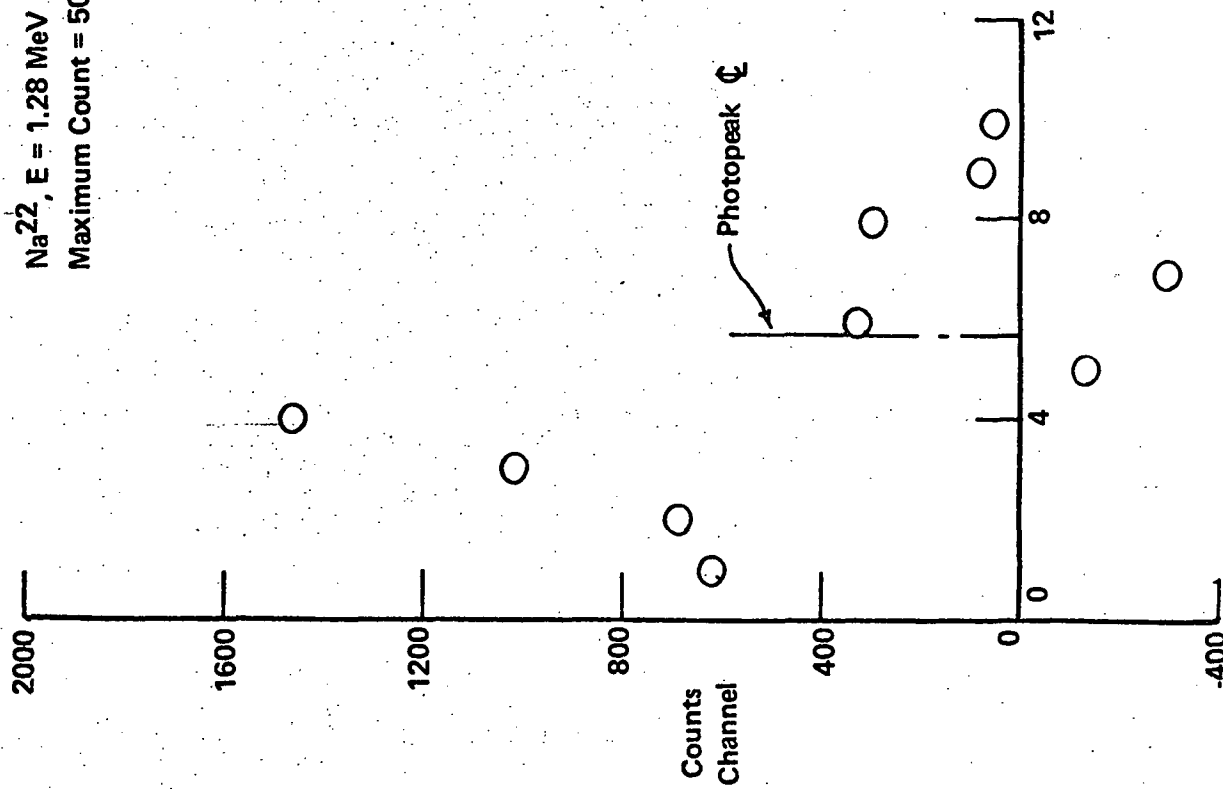


Figure V-7

Co<sup>60</sup>, E = 1.333 MeV  
Maximum Count = 57,738

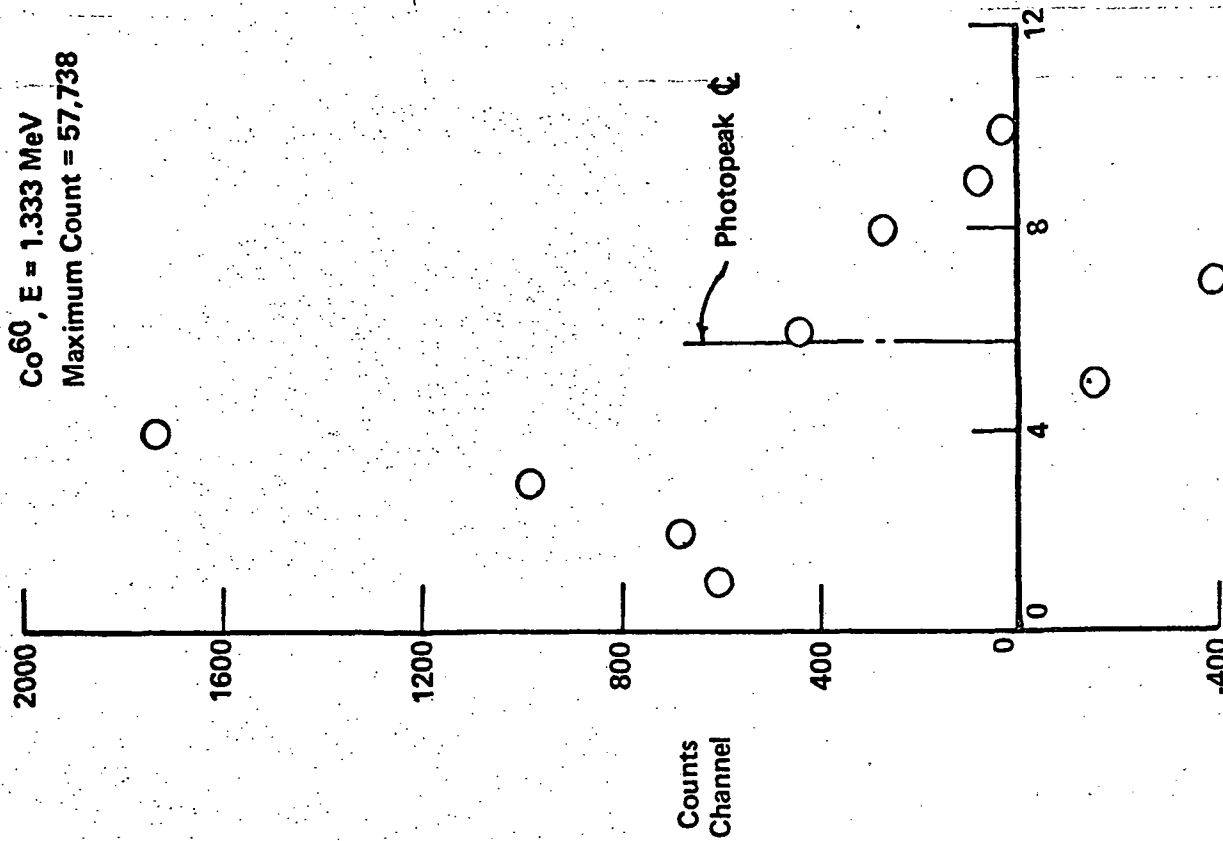


Figure V-8

1/ 18/ .0 X  
 2/ 18/ .0 X  
 3/ 18/ .0 X  
 4/ 18/ .0 X  
 5/ 18/ .0 X  
 6/ 18/ .0 X  
 7/ 18/ .0 X  
 8/ 18/ .0 X  
 9/ 18/ .0 X  
 10/ 18/ .0 X  
 11/ 18/ .0 X  
 12/ 19/ .0 X  
 13/ 19/ .0 X  
 14/ 20/ .0 X  
 15/ 23/ .0 X  
 16/ 27/ .0 X  
 17/ 36/ .0 X  
 18/ 49/ .0 X  
 19/ 69/ .0 X  
 20/ 91/ .0 X  
 21/ 114/ .0 X  
 22/ 128/ .0 X  
 23/ 135/ .0 X  
 24/ 127/ .0 X  
 25/ 111/ .0 X  
 26/ 87/ .0 X  
 27/ 65/ .0 X  
 28/ 46/ .0 X  
 29/ 33/ .0 X  
 30/ 24/ .0 X  
 31/ 20/ .0 X  
 32/ 18/ .0 X  
 33/ 16/ .0 X  
 34/ 16/ .0 X  
 35/ 16/ .0 X  
 36/ 16/ .0 X  
 37/ 16/ .0 X  
 38/ 16/ .0 X  
 39/ 16/ .0 X  
 40/ 16/ .0 X  
 41/ 16/ .0 X  
 42/ 16/ .0 X  
 43/ 16/ .0 X  
 44/ 16/ .0 X

Add 335 to Channel 1  
 Figure V-9  
 Ce<sup>139</sup>, E = .166 MeV

1/ 17/ .0X  
 2/ 17/ .0X  
 3/ 17/ .0X  
 4/ 17/ .0X  
 5/ 17/ .0X  
 6/ 17/ .0X  
 7/ 17/ .0X  
 8/ 18/ .0 X  
 9/ 18/ .0 X  
 10/ 18/ .0 X  
 11/ 21/ .0 X  
 12/ 30/ .0 X  
 13/ 47/ .0 X  
 14/ 78/ .0 X  
 15/ 115/ .0 X  
 16/ 134/ .0 X  
 17/ 129/ .0 X  
 18/ 93/ .0 X  
 19/ 58/ .0 X  
 20/ 33/ .0 X  
 21/ 22/ .0 X  
 22/ 18/ .0 X  
 23/ 17/ .0 X  
 24/ 16/ .0 X  
 25/ 16/ .0 X  
 26/ 16/ .0 X  
 27/ 16/ .0 X  
 28/ 16/ .0 X  
 29/ 16/ .0 X  
 30/ 16/ .0 X

Add 364 to Channel 1  
 Figure V-10  
 Hg<sup>203</sup>, E = .279 MeV

1/	17/	.0x
2/	17/	.0x
3/	17/	.0x
4/	17/	.0x
5/	17/	.0x
6/	17/	.0x
7/	18/	.0 x
8/	23/	.
9/	45/	.
10/	99/	.
11/	135/	.
12/	102/	.
13/	45/	.
14/	21/	.0x
15/	16/	.
16/	16/	.
17/	16/	.
18/	16/	.
19/	16/	.
20/	16/	.

Add 378 to Channel 1

Figure V-11

$\text{Sr}^{85}$ , E = .514 MeV

1/	17/	.0x
2/	17/	.0x
3/	17/	.0x
4/	17/	.0x
5/	14/	.0 x
6/	22/	.
7/	51/	.
8/	125/	.
9/	135/	.
10/	59/	.
11/	21/	.
12/	16/	.
13/	16/	.
14/	16/	.
15/	16/	.
16/	16/	.

Add 366 to Channel 1

Figure V-12

$\text{Cs}^{137}$ , E = .6616 MeV

Add 368 to Channel 1

Figure V-13

Mn<sup>54</sup>, E = .835 MeV

1/	17/	.0x
2/	17/	.0x
3/	17/	.0x
4/	17/	.0x
5/	18/	.0 x
6/	29/	.
7/	88/	.
8/	135/	.
9/	57/	.
10/	19/	.
11/	16/	.
12/	16/	.
13/	16/	.
14/	16/	.

0 x

0x

Add 378 to Channel 1

Figure V-14

Zn<sup>65</sup>, E = 1.114 MeV

1/	17/	.0x
2/	17/	.0x
3/	17/	.0x
4/	18/	.0 x
5/	19/	.0 x
6/	41/	.
7/	135/	.
8/	106/	.
9/	23/	.
10/	16/	.
11/	16/	.
12/	16/	.

0

x

Add 379 to Channel 1

Figure V-15

Co<sup>60</sup>, E = 1.333 MeV

1/	17/	.0x
2/	17/	.0x
3/	17/	.0x
4/	18/	.0 x
5/	23/	.
6/	79/	.
7/	135/	.
8/	39/	.
9/	17/	.
10/	16/	.
11/	16/	.
12/	16/	.

0 x

x0

0x

Add 171 to Channel 1

Figure V-16

$Zn^{65}$ ,  $E = 0.51$  MeV

1/	46/	.
2/	47/	.
3/	46/	.
4/	49/	.
5/	66/	.
6/	135/	.
7/	112/	.
8/	54/	.
9/	47/	.
10/	46/	.

ox  
ox  
ox  
ox  
ox  
ox  
ox  
ox  
ox  
ox

Add 334 to Channel 1

Figure V-17

$Co^{60}$ ,  $E = 1.173$  MeV

1/	22/	.	ox
2/	21/	.	.
3/	22/	.	ox
4/	24/	.	ox
5/	58/	.	ox
6/	135/	.	ox
7/	52/	.	ox
8/	21/	.	ox
9/	19/	.	ox
10/	19/	.	ox

ox  
ox  
ox  
ox  
ox  
ox  
ox  
ox  
ox  
ox

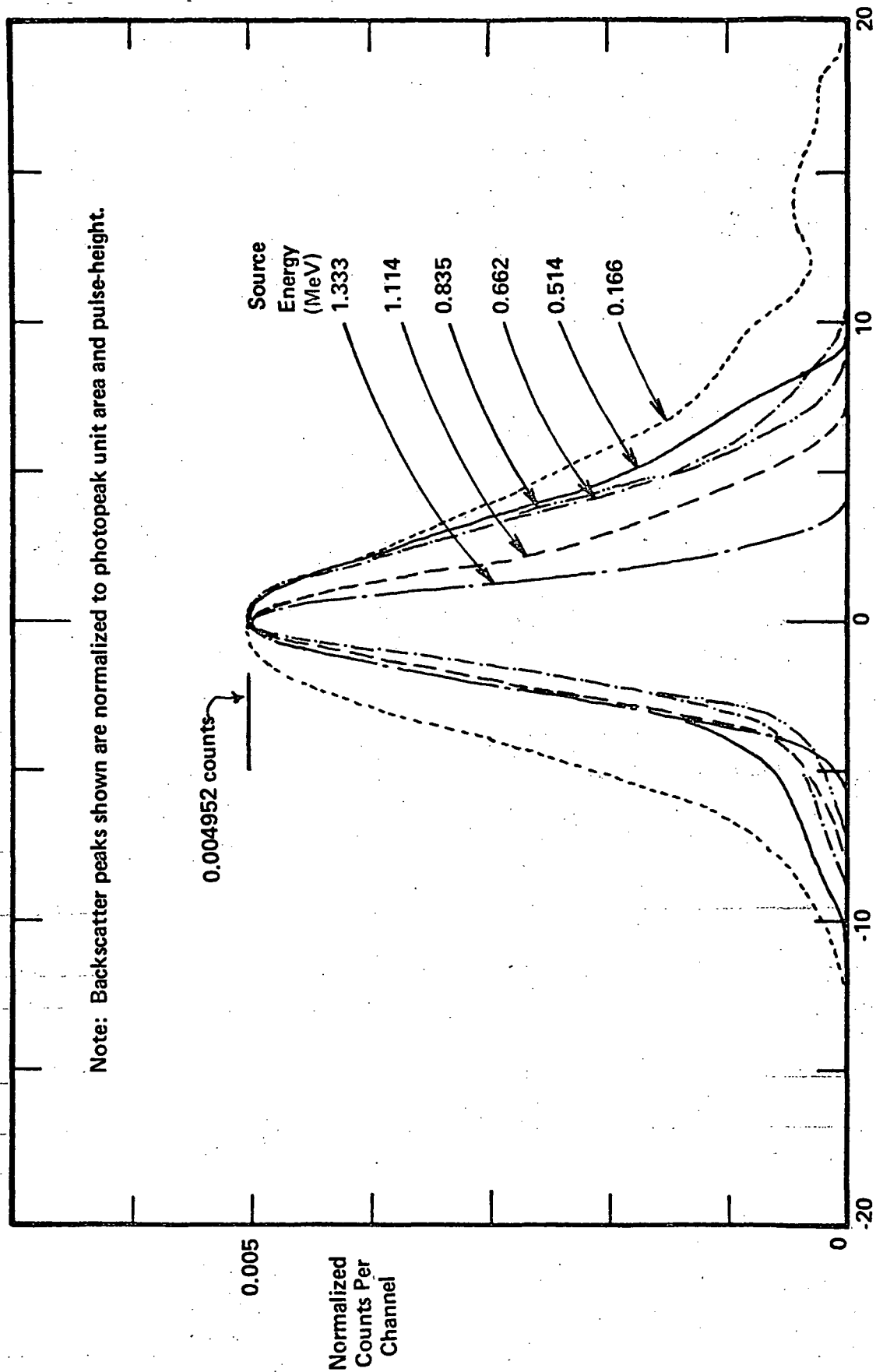
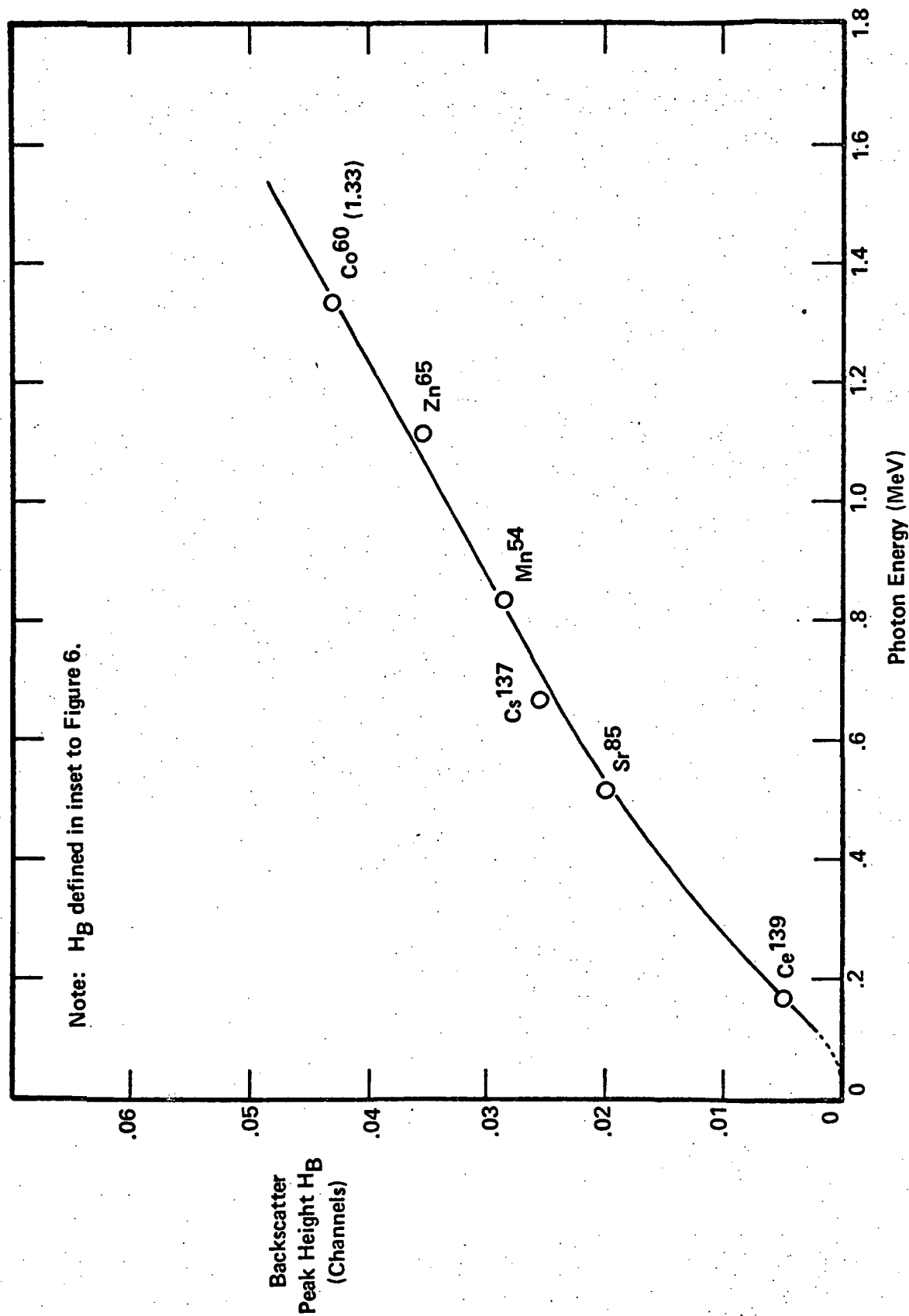


Figure V-18  
Normalized Backscatter Peaks



Backscatter Peak Height as a Function of Photon Energy  
Figure V-19

## APPENDIX VI

REPRODUCTION OF APPENDIX II OF REFERENCE ( 2 ):

### PHOTOPEAK FUNCTION FITTING

Note: The Following Are Approximately Equivalent in This Appendix:

CUBED ,	read as	CUGEL
STDFIT ,	read as	STDFT3
GUESS ,	read as	PKFUN
PHOFRA ,	read as	RESFUN



## APPENDIX II

### PHOTOPEAK FUNCTION FITTING

The pulse-height analyzer spectral photopeak counts,  $y(x_i)$ , are fitted to the Gaussian-plus-straight-line non-linear function

$$f(x_i) = f(x_i; p_j) = \frac{G p_3 e^{-\frac{(x_i - p_1)^2}{2p_2^2}}}{p_2} + p_4 x_i + p_5 \quad (1)$$

where

- $p_1$  = photopeak mean pulse-height.
- $p_2$  = photopeak standard deviation.
- $p_3$  = photopeak area.
- $p_4$  = slope of photopeak assumed straight-line base.
- $p_5$  = intercept of photopeak assumed straight-line base.
- $G$  = 0.3989423, a Gaussian constant.
- $i$  =  $\ell, \ell+1, \dots, n$ ;  $\ell$  and  $n$  are input to code CUBED.
- $j$  =  $1, 2, \dots, m$ ;  $m=5$  in equation (1), and in code CUBED.

The partial derivatives of equation (1), with respect to the parameters,  $p_j$ , are determined as

$$\left. \begin{aligned} f_{p_1} &= \left( \frac{\partial f}{\partial p_1} \right)_i = f(x_i)^* \left( \frac{x_i - p_1}{p_2^2} \right) \\ f_{p_2} &= \left( \frac{\partial f}{\partial p_2} \right)_i = \frac{f(x_i)^*}{p_2} \left( \left( \frac{x_i - p_1}{p_2} \right)^2 - 1 \right) \end{aligned} \right\} \quad (2)$$

$$f_{p_3} = \left( \frac{\partial f}{\partial p_3} \right)_i = -f(x_i)^* / p_3$$

$$f_{p_4} = \left( \frac{\partial f}{\partial p_4} \right)_i = x_i$$

$$f_{p_5} = \left( \frac{\partial f}{\partial p_5} \right)_i = 1$$

(2)

where

$$f(x_i)^* = f(x_i) - p_4 x_i - p_5$$

Equations (1) and (2) are coded in subprogram FUNUS. Equation (1) is fitted to the experimental data,  $(x_i, y_i)$ , according to the iterative least-squares method of differential correction (34); it is coded in subprogram STDFIT. This method, as it is applied in code CUBED, is outlined as follows:

A set of non-linear residual equations are defined and after some manipulation expressed as first linear approximations. An initial estimate of values of the fitting function parameters is employed for the first approximation (iteration). The linearized approximation residual equations are minimized by the method of least-squares such as to generate a set of normal equations which are in turn solved to determine the coefficients. These differential correction coefficients are applied additively to the current (initial on first iteration) parameter values to obtain the values for the next (second, third, etc.) iteration. This is repeated until the sum of the squares of the residuals (between function and experimental values) differ by less than some preassigned value, as determined for consecutive iterations.

The set of non-linear residual equations are defined as;

The set of non-linear residual equations are defined as:

$$R_i = f(x_i; p_j^{(k)}) - y(x_i) \quad (3)$$

which may be rewritten as

$$R_i = f(x_i; p_j^{(k)} + q_j^{(k)}) - y(x_i) \quad (4)$$

where

$p_j^{(0)}$  = initially estimated value of  $j^{\text{th}}$  parameter.

$p_j^{(k)}$  = value of  $j^{\text{th}}$  parameter for iteration  $k$ .

$k$  = iteration index

$q_j^{(k)} = p_j^{(k)} - p_j$ , differential correction coefficient  
(ideally equal to zero).

Expanding equation (4) by means of Taylor's theorem for a function of several variables, it may be seen that

$$R_i = f(x_i; p_j^{(k)}) - y(x_i) + \sum_{j=1}^m q_j^{(k)} \left( \frac{\partial f}{\partial p_j^{(k)}} \right)_i + \delta \quad (5)$$

where

$\delta$  = neglected higher order terms in  $p_j$ .

Thus equation (5) can be expressed as:

$$R_i = r_i + \sum_{j=1}^m q_j^{(k)} \left( \frac{\partial f}{\partial p_j^{(k)}} \right)_i \quad (6)$$

a set of residual equations, linear in  $p_j$ .

Minimizing as

$$\sum_{i=1}^n R_i^2 = u(p_j^{(k)}) \quad (7)$$

The normal equations may be written as:

$$\left. \begin{aligned} \left( \sum f_{p_1 p_1} \right)_i q_1 + \left( \sum f_{p_1 p_2} \right)_i q_2 + \dots + \left( \sum f_{p_1 p_m} \right)_i q_m + \sum f_{p_1 r_i} &= 0 \\ \left( \sum f_{p_2 p_1} \right)_i q_1 + \left( \sum f_{p_2 p_2} \right)_i q_2 + \dots + \left( \sum f_{p_2 p_m} \right)_i q_m + \sum f_{p_2 r_i} &= 0 \\ \vdots &\vdots \\ \left( \sum f_{p_m p_1} \right)_i q_1 + \left( \sum f_{p_m p_2} \right)_i q_2 + \dots + \left( \sum f_{p_m p_m} \right)_i q_m + \sum f_{p_m r_i} &= 0 \end{aligned} \right\} \quad (8)$$

and solved for the differential correction coefficients  $q_j^{(k)}$ .

Iterating is continued with the iteration parameter values determined as

$$p_j^{(k+1)} = p_j^{(k)} + q_j^{(k)} \quad (9)$$

until the arresting criterion employed is satisfied. Iterating is arrested when

$$\left| \frac{S^{(k-1)} - S^{(k)}}{S^{(k)}} \right| \leq e'$$

where

$e'$  = an assigned tolerance value;  $e' = 10^{-5}$  in code CUBED subprogram STDFIT.

$$S^{(k)} = \sum_{i=1}^n (y(x_i) - f(x_i; p_j^{(k)}))^2 \cdot W(x_i)$$

$W(x_i)$  = set of statistical weights;  $= (y(x_i))^{-1/2}$  in code CUBED subprogram STDFIT.

In general, subprogram STDFIT ceased fitting equation (1) at  $k=5$ . Subprogram GUESS communicates the  $p_j^{(0)}$  to subprogram STDFIT semi-automatically, i.e., it requires  $\ell$  and  $n$ , the lower and upper fitting indices to be input to subprogram PHOFRA (encoded as NSJ and NFNJ). Equation (8) is solved according to the conventional Gauss-Jordan pivoting method<sup>(35)</sup>.